AN INTRODUCTION TO BIOLOGY

FOR STUDENTS IN INDIA

BY

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WITH [illegible] PLATES OF DIAGRAMS

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PREFACE.

Owing to the new regulations, it has become necessary for all who wish to graduate in Medicine at the Calcutta University to obtain knowledge of the structure of animals by dissection. The anatomy of vertebrate types is described in many good books, but the common invertebrate animals of Bengal, which are peculiar to the country, have not been described hitherto in any text-book. It is necessary that the types for dissection should be of common animals, which may be obtained in large quantities. In England even Protozoa can be conveniently obtained by purchase. This is not the case in India; but the source of the material for our classes must be as certain as in other countries. The types selected are not in all cases those required by the University syllabus. Some of the types mentioned therein, such as Euglena, Sphenopus, Eunice, Bipalium, and certain Echinoderms, cannot be obtained in sufficient quantities for classes which may number as many as one hundred and fifty students. Because it was urgently required, the book has been written somewhat hurriedly, and is therefore likely to contain errors. I shall be grateful to other teachers in India who may point

them out. In drawing the figures, I have tried to express only what I have seen; when possible, the outline was guided by the camera lucida.

The last chapters of the book deal with Evolution, Variation, and Heredity in a simple manner. It is difficult to decide what should be taught about these debatable subjects, but as they are fast growing in importance at the present day, they should, I think, be introduced to the students' notice.

I have treated these subjects here much as in the lecture room – that is to say, in the way that has seemed best to me as a result of observation and reading. My chief endeavour has been to awaken the interest of students in these subjects. However much of truth or untruth the teaching may contain, the interest shown in it hitherto by a number of my students has been encouraging.

I am much indebted to Messrs. Macmillan & Co. for their kindness in allowing me to make use of certain illustrations (viz. Plate XIV., *in toto*; Plate III., Fig. H; Plate VI., Fig. C); and to Messrs. Smith, Elder & Co. for the kind permission to make a quotation from Marshall & Hurst's "Practical Zoology."

R. E. L.

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INTRODUCTION

(To the Student)

A student who, for the first time, enters upon a course of training in Biology or in any other science, will find that the subject is somewhat different from other kinds of learning. He will find that his attention is directed towards material things, their appearance and behaviour. The observations and thoughts of those who have examined the material things of the world are expressed in many books. These books are the guides which will help the student to acquire experience; but he can only gain experience of things by examining them for himself. Science is our united experience of material things as expressed in books. The student must approach science in a spirit of inquiry as to whether his observations agree with those of others, and as to whether the thoughts of others, as expressed in the books, find a natural reflection in his own mind. He is at liberty to form his own opinions; the only test of the worth of his opinions to himself is that they shall be clear and definite, and not uncertain or hazy.

Biology treats of material things which are endowed with life. The animal and vegetable kingdoms are so

large that a man can only study a small part of them. Suppose for example that, of several independent observers, each studies a different part of the animal or vegetable kingdom: one may study the four-footed, hairy animals, another may examine the fish, the flowering plants, or the ferns. They examine them in all their aspects, as regards their minute structure, their method of reproduction, and in their relation to the other living things which surround them. Although the things which they examine are in many ways dissimilar, each independent observer will discover certain truths which, on comparison, will be found to agree with those discovered by the other observers. Certain general truths are therefore applicable to the whole range of living things. It is these general truths which constitute the Science of Biology. The importance of Biology becomes manifest as soon as it is clearly recognized that mankind is one with all living things.

✓THE METHOD OF STUDY.—The student must seek for knowledge of living things from the things themselves; he must examine their outward form, their internal anatomy, and their minute structure as seen with the help of the microscope. Having understood the structure of an animal by dissection and observation, he must express it in some way, in order that his impressions may be clear, and that he may compare them with those of other people. The best method of expressing such observations is by drawing. Hence, under the new regulations of the Calcutta University,

candidates for examination in Biological subjects must submit their books of drawings in order to show that they have personal experience of the subject. This rule is vexatious to those students who possess the gift of artistic expression in a very small degree. But it is not necessary that the drawings should possess any artistic merit; they may be the simplest of diagrams, provided that they express the results of carefully made observations.

The difficulty of representing the relative size and positions of the various features of a dissection may be overcome by using dividing compasses. By means of these instruments, the size of the various organs and the distance between them may be measured in the dissection, and transferred directly to the paper. Those students, to whom it is a particularly difficult matter to represent the structure of an animal by drawing, should consider that they are inferior to their fellows in the clearness of their mental pictures of structures in general, and that they are therefore in special need of that training which they will obtain in their efforts to overcome the difficulty.

THE USE OF THE MICROSCOPE.- The student will be shown how to use the microscope in the laboratory when the instrument is before him; it is therefore unnecessary to deal with the subject at length, but it is well to emphasize two important rules which are often violated, even by those who have used the instrument several times.

The Focus. —It is necessary at all times, and especially when examining objects with the higher powers of magnification, to keep the hand on the fine adjustment screw, and to constantly alter the focus of the instrument. Even the minutest object has an upper and a lower surface, and is bounded by sides, but beneath the microscope these several aspects cannot all be seen at the same time. In the early part of their training, students often fail to understand the form of microscopic objects because they have not learnt the habit of constantly altering the focus of the instrument. Suppose for example, that an observer is trying to understand the shape of three microscopic objects, which, unknown to him, are in reality very minute cylindrical glass bottles. They are all alike in shape, but they lie in different positions, and because of this they will each present a different appearance when examined under the microscope. Through a microscope we look down upon an object from above, therefore a bottle that is standing upright will appear simply as a circle of glass; another, which is leaning obliquely against it, will appear as an oval figure; a third, which is lying on its side, will probably be out of focus, and therefore invisible; but, it it can be seen, it will be the only one of the three which will give the observer a clue to the form of the object—in it he will be able to see the sides of the bottle in all their length, the bottom, the neck, and the cork, if there is one. While the focus screws are at rest, all that the observer can see lies in a single

plane, which is like a section cut horizontally through the various objects. This section is called an optical section. It is impossible to form an opinion as to the whole form of a solid body by examining one section of it, but by shifting the focus many optical sections are brought into view, the upper and lower surfaces of the object become visible, and the form of the whole object becomes known to the observer.

It is necessary to lay stress on this simple rule, for it often happens that students will sit in the class-room with hands folded, waiting for the demonstrator to show them something which they cannot see, simply because it is out of focus. Just as in dissecting the hand helps the eye to search, so also, in using the microscope, the hand must never be at rest, but should manipulate the focus adjustment screw.

The Light Supply. -Microscopic objects of an animal and vegetable kind can only be examined properly when they are transparent. If they are opaque, they must be rendered transparent by treatment, or they must be cut up into slices or sections which are so thin that light can pass through them. Pieces of animal and vegetable matter become more or less formless when dry; they must therefore be examined in some fluid. A simple method of examination is to place the object in a drop of water upon a piece of glass called a slide. The drop containing the object is then covered with another piece of very thin glass, which is called a cover slip. The slide is placed upon the stage of the microscope;

light is reflected from the mirror of the microscope upwards through the glass slide, through the object and the water in which it lies, and the superimposed cover slip, and finally through the lenses of the instrument and into the eye of the observer. Most microscopes are provided with two mirrors, a flat one and a concave one, which are set back to back, and form a single pivoted disc. Between the mirror and the stage there is, even in the simplest microscopes, some contrivance by means of which the operator can stop as much or as little of the reflected light as he wishes. In some microscopes this contrivance takes the form of a metal plate or diaphragm, which is pierced by a number of circular apertures of different sizes, any one of which may be interposed between the mirror and the stage; other microscopes have an "iris diaphragm," which contains a single aperture of variable size, like the pupil of the eye.

In order to examine a small transparent object with the microscope to the best advantage, the light from the mirror must be regulated. The practical importance of controlling the light will become known to the student after he has made the following experiment: Prepare a minute filament of glass by melting the middle of a glass rod in a flame and quickly drawing the ends apart, place a small piece of it in water on a glass slide, and examine it under the low power of the microscope. Regulate the light in the following manner: —

1. Use the flat mirror, and let the aperture of the diaphragm be as small as a pin's head.

2. Use the concave mirror, and let the aperture be wide open.

Under the first conditions the filament will be very easy to see, because its margins are defined by broad black lines, but under the second conditions the margins transmit light to the eye, so that the object is less easy to see. The student will understand this when he has learnt how light is refracted or bent as it passes from one transparent substance into another of different density. The practical point to be learnt from the experiment is that a delicate and colourless object, such as a bacillus or the tail of a spermatozoon, is invisible when illuminated by the whole light of a concave mirror; this fact must never be forgotten.

Under the conditions of the first experiment the bold definition of the object is due to the refraction of the light passing through it; in other words, we may explain the phenomenon as being due to the fact that the glass filament is of greater density than the water in which it is lying. This may be proved by examining the filament in some fluid of greater density than water, such as Canada balsam (or glycerine). In this condition the object is almost invisible, for the glass filament and the balsam are nearly of the same density, and the light passes straight through both of them without being refracted.

STAINING.—If in the last experiment we had used

a filament of red or blue glass, it would have been very easy to see because of its colour, and, as a whole, it would present a truer appearance than when defined by thick black lines as in the conditions of the first experiment. Moreover, it would be most visible when illuminated by strong light—that is to say, by the unreduced light of a concave mirror. This explains the custom of staining microscopical objects, and indicates how stained objects should be examined. Some simple methods of staining will be described subsequently. The process of staining and mounting objects in Canada balsam is not usually carried out by the students in an elementary course, but objects which have been so treated are frequently offered for observation. Briefly the process is as follows: After being stained, the object is first soaked in alcohol and water, then in absolute alcohol until all water is subtracted from it. The object is then placed in clove oil, and subsequently transferred to the Canada balsam, in which it is mounted permanently on a glass slide. An important reason for staining microscopical objects is to render certain parts of them visible by contrast. Some of the substances which constitute an organism absorb various stains more readily than others; some of them have a special power of taking up certain stains. The peculiar relations between such substances and the various kinds of colouring matter is of great use in microscopical investigations.

Dissection.—In order to examine the structure of

any animal to the best advantage, it is necessary to commence the dissection in a particular manner, and to proceed from start to finish in orderly succession. In the case of each type the various steps of the dissection are indicated in the foregoing pages. These steps should be carefully followed by the student, but as there is more to be seen in the structure of the animals than is described in these pages, the book should not be followed too closely. The student must form the habit of learning from his dissection: he should treat the book merely as a guide.

INJECTION. A good method of investigating some of the hollow sac-like organs which occur in many animals is by the injection of coloured fluids. This is easily performed in the case of small animals by means of an ordinary hypodermic syringe. A suitable fluid for injection is pure carmine, which can be finely ground up in water but does not dissolve. It is necessary that the carmine should be pure. As purchased in India, this pigment is usually adulterated with soluble dyes, such as eosin, which stains the walls of the organs, and diffuses through them so as to spoil the effect of the injection.

Injection with a hypodermic syringe is easy to perform. The hollow needle must be thrust through the wall of the organ into the cavity with some care, so that the opposite wall is not damaged; the piston of the syringe must be pressed slowly, otherwise the cavity which is being injected may burst. Injection is often

performed in order to demonstrate the vascular systems of those animals which have colourless blood, but the method is also very useful to discover the outlet and communications of hollow organs, such as the kidneys of the snail and the prawn.

CHAPTER I

THE PROTOZOA

ANIMALS are composed of living material, which is called protoplasm. Except in the simplest animals the protoplasm is arranged in the form of separate units or cells, each a minute piece of living matter. A complex animal is composed of a vast number of these cells, which are of different kinds and are combined to form the fabric of the body, much in the same way as bricks, beams, and tiles are combined to form a house. It is the custom to regard the body of the simplest animals as though it were one cell; that is to say, it may be compared, though not exactly, with one of the units which combine to form a complex animal. The simplest animals are, therefore, described as unicellular, while others are called multicellular. Unicellular animals are, as a group, named the Protozoa. Multicellular animals are named Metazoa.

AMOEBA.—The Amoeba is among the simplest of the Protozoa. The body of an Amoeba consists of a minute portion of naked protoplasm, which is not constant in its form, but variable from moment to moment. Amoebae are very minute; with the aid of a microscope they may

be found in various situations—among vegetation in fresh-water ponds, in water which contains rotting organic material, and also as parasites in the intestines of many of the higher animals. In company with other kinds of Protozoa they may be obtained from what are called infusions. To make an infusion a quantity of hay or leaves must be placed in water. After about twenty-four hours or more, according to the temperature, the water looks yellowish, and the surface becomes covered with an opaque film. If some of this film be removed and examined under the microscope, it will be seen to contain numerous minute rod-like bodies, many of which move actively; these are bacteria which have emerged from minute round bodies called spores, just as a chicken emerges from its egg. The spores of the bacteria are present everywhere, attached to the hay and floating in the air. They are not killed by ordinary heat and drought; they are reproduced in the bodies of parent bacteria. The appearance of the bacteria in the water marks the first stage of putrefaction. Soon after the appearance of the bacteria, various Protozoa may be found in the infusion; these have emerged from bodies called cysts, which also are distributed everywhere. The Protozoa feed actively upon the bacilli and upon one another.

As an example of an Amoeba, a large form which is sometimes found in infusions will be first described. To obtain it, place a piece of straw from a two or three days' infusion upon a glass slide, and scrape it with a

knife. Place a cover-slip over the dirty greyish-looking fluid which has exuded, and examine it under the low power of the microscope. Among the various organisms in the fluid may sometimes be seen an Amoeba large enough to be recognized without much difficulty. When found, examine it under the high power.

The Amoeba is a piece of living material or protoplasm; it is translucent, but not equally so throughout; it is surrounded by an outer layer, or ectoplasm, which is almost as clear and transparent as glass. The more central portion, or endoplasm, is opaque, and contains numerous granules. The shape of the Amoeba is not constant for any length of time, but changing, owing to the protrusion of blunt lobes which may be thrust out from any part of the surface. When such a lobe or pseudopodium is thrust out, a flowing movement of the granules of the endoplasm may be observed. The granules stream down the central axis of the pseudopodium until they reach the blunt end, where they are reflected outwards, so that in returning to the main body, they take a superficial course. The movement within a pseudopodium is therefore somewhat like the movement within a fountain of water which is forced vertically into the air. When the animal wishes to move in a certain direction, a large pseudopodium is thrust out in that direction and the bulk of the endoplasm is poured into it, so that the whole animal shifts its position. Pseudopodia are also thrust outwards towards particles of food material, which become engulfed

within the ectoplasm to be passed into the endoplasm, where they are digested.

Within the endoplasm is a spherical body which is somewhat opaque, this is the nucleus; sometimes two nuclei are present. (Every cell of a multicellular animal contains a nucleus; it is because of this fact that the body of an Amoeba or other Protozoon appears to be a single cell.) There are many particles in the endoplasm which have the same appearance as the various particles in the surrounding water; they are ingested food material. Sometimes they can be seen to lie within minute spherical spaces in the endoplasm, which are called food vacuoles. Another kind of vacuole can always be seen in the endoplasm; this is much larger, and is called the contractile vacuole. It should be watched while it expands slowly until it bursts like a bubble. When large it is near the surface; and if then it be viewed from the side, the ectoplasm which covers it may be seen to bulge and become thinner and thinner, until it ruptures at a point and the contents of the vacuole are discharged. If it is viewed from above and not from the side, the ectoplasm around the point of discharge assumes a radiating appearance, which is perhaps due to minute folds of the surface, which must naturally form as the bulged ectoplasm sinks back into its normal position. As soon as the contractile vacuole has discharged its contents from the body, it again commences to fill and expand as before. The contractile vacuole is doubtless an excretory organ, the fluids that

are discharged must contain the waste products of metabolism (Chap. VIII.).

Other Kinds of Amoebae.—A smaller kind of Amoeba is common among the dark green slime which accumulates in wet gutters. With the help of a microscope we can see that the slime from a gutter consists of a tangled mass of green filaments, which are minute plants called Algae. A small piece of such material should be placed upon a slide in a drop of water, and broken up very finely with needles. By this means the Amoebae become dislodged from among the green filaments. The slide should be covered and examined. Amoebae found in this way, as well as those found among Algae in fresh-water ponds, are smaller than the kind just described, and have long, thin pseudopodia which are composed of clear ectoplasm throughout; that is to say, a granular axis cannot be seen in them. Otherwise, these Amoebae are like the kind just described, but they can be obtained with much greater certainty. Another kind may generally be obtained from the intestine of the common cockroach. Amoebae which live in the intestines of multicellular animals are called Endamoebae; one kind of Endamoeba causes dysentery and liver abscess in man. To obtain Amoebae from the cockroach, kill the insect with chloroform and pull off the end of the abdomen. The intestine will be seen as a black chord stretching between the torn-off portion and the rest of the body. Cut out a portion of this and place it upon a slide in a drop of salt solution. The intestine is a membranous tube with

black contents; it must be cut open with fine scissors, the contents scraped from the inner wall and mixed in the salt solution. The mixture must be covered and examined; various parasites can usually be seen—thread-worms (Oxyurus), large ciliated Protozoa (Nyctotherus), and numerous Endamoebae. The Endamoebae are small, and must be sought for under the high power of the microscope. They are peculiar in being very transparent, as though entirely composed of ectoplasm, in which are embedded a few large food particles. They are sometimes very active, and thrust out rounded pseudopodia with great rapidity; at other times they assume a spherical form, as though resting. Although large Amoebae are not easily obtained in infusions, minute Amoebae may almost always be found in them. Such Amoebae are often very active; but vacuoles and even nuclei cannot easily be seen in them: they are perhaps stages in the life-history of other Protozoa.

When the water in which Amoebae live is becoming dried up, they undergo encystment, assuming a spherical shape and surrounding themselves with an impervious coat or cyst. In this form they can resist drought and moderate heat; they may be scattered by the wind until they find themselves in water again. Amoebae have been seen issuing from such cysts.

The reproduction of Amoeba is by simple division of the body, and is preceded by simple division of the nucleus. The round nucleus assumes the shape of a dumb-bell or hour-glass, and the two halves become

separated. After division of the nucleus, the entire body undergoes a similar change; on separation, each half of the body contains one-half of the old nucleus. This method of reproduction is essentially different from that of multicellular animals. In the reproduction of higher animals, portions of the body are thrown off from time to time to form offspring, but the parent body must finally undergo death. In Amoeba, the parent body divides and forms two offspring, so that it does not die, but becomes continuous in the offspring. Much remains to be discovered about the life-history of Amoebae.

Protozoa, such as Amoeba, which change their shape and thrust out pseudopodia are placed together in a group and named Lobosa. Some Lobosa form hard protecting shells for themselves. Of these the form known as Difflugia is sometimes found in Indian ponds. This Protozoon forms a balloon-shaped shell by cementing together particles of sand. The nucleus and most of the protoplasm remains within the shell, active pseudopodia are thrust out through an opening in the shell which represents the mouth of the balloon.

There are certain groups of Protozoa which must be passed over hurriedly, although each group is large enough to form the study of a lifetime.

THE FORAMENIFERA

These Protozoa live in the sea, floating near the surface or crawling on the bottom. Like Difflugia they

form a hard shell, sometimes of sand, more often of calcium carbonate, which they secrete from the sea-water. The shells are always perforated by minute round apertures. The protoplasm lies partly within the shell and partly around it, and is continuous through the apertures. The mature shell is generally composed of several chambers. At the commencement of its life, the young Protozoon forms for itself a single chamber resembling that of Difflugia, except that it is perforated; when it becomes too large for its shell it forms another, which is fixed to the first. Many others are formed in succession as the animal grows. The several chambers are arranged in different ways among the different kinds —in a straight line, in a spiral, or in other ways. The Foramenifora are of importance as builders of the earth's surface. They are very numerous in the sea; by their united power of secretion they convert vast quantities of dissolved calcium salts into solid calcium carbonate, which is added to the crust of the earth; for when a Foramenifera dies, its shell sinks to the bottom of the ocean and remains there. In much of its area, the mud of the ocean is almost entirely composed of shells of Foramenifera, and it is also known that some of the rocks which constitute the earth's surface are also largely composed of the minute shells of Foramenifera which lived in bygone ages (Chap. IX.). The Foramenifera differ from the Lobosa in their method of reproduction.

The Radiolaria are another large group of Protozoa which also are found in the sea; they mostly secrete

perforated shells of silica, which sink to the floor of the ocean and remain there.

THE SPOROZOA

These will be described in more detail, as they are common and sometimes cause disease. A mature Sporozoon is generally covered outwardly with a delicate and firm layer or cuticle, which prevents the protrusion of pseudopodia, but may not prevent all movement. Contractile and other vacuoles do not occur in Sporozoa, because the method of nutrition is different from that of other Protozoa. The Sporozoa live as parasites within the bodies of multicellular animals; although they may often be found lying free in the various cavities of the body, they always pass some part of their life-history within a cell of their host, by the juices of which they are nourished.

MONOCYSTIS.—A large Sporozoon named Monocystis may be obtained from the organs known as the seminal vesicles of the earth-worm. It seems impossible to find an earth-worm which is not highly infected with this parasite. In India the degree of infection is much greater than in more temperate climates. If a small portion of one of the seminal vesicles of an earth-worm (Chap. III.) be pressed into a drop of salt solution upon a slide the drop will be rendered turbid. With the naked eye the drop may be seen to contain minute white specks, which are the Monocystis. The drop should be

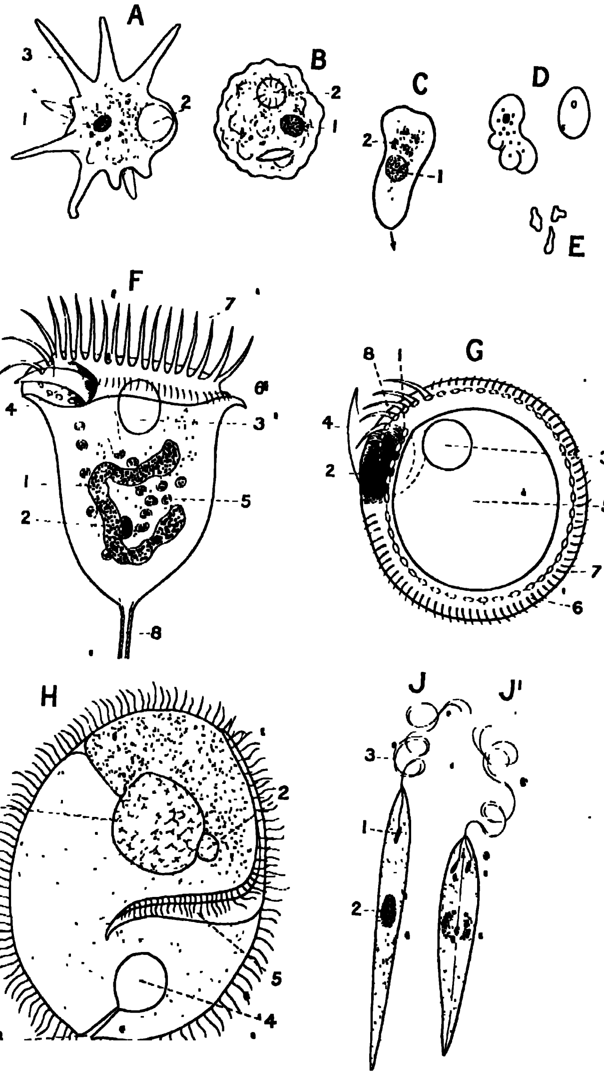
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PLATE I.

Various Protozoa.

A. An active Amoeba from fresh water. 1. Nucleus; 2. Contractile vacuole; 3. Pseudopodium.

B. The same in a state of contraction.

C. An Amoeba from the intestine of a man who was suffering from dysentery. 1. the nucleus; 2. remains of ingested corpuscles from the man's blood.

D. Amoeba from the intestine of a cockroach.

E. Amoebulae from an infusion.

F. Vorticella (side view). 1. macronucleus; 2. micronucleus; 3. contractile vacuole; 4. undulating membrane; 5. food vacuole; 6. paroral cilia; 7. adoral cilia; 8 contractile fibre.

G. Vorticella (from above); 1 and 8 indicate the first and last cilia of the adoral row; 2. vestibule; 5. disc. (For convenience, only the bases of the adoral cilia are shown.)

H. Nyctotherus from the intestine of the cockroach; 1. macronucleus; 2 micronucleus; 3. anus; 4. contractile vacuole; 5. vestibule.

J. Herpetomonas from the intestine of a house-fly. 1. kinetonucleus; 2. trophonucleus; 3. flagella.

J'. Herpetomonas undergoing fission.

(N.B.—Figures A—H are drawn approximately to the same scale × 450. J—J' × 2000)

covered and examined under the microscope. The many parasites which are visible are not all alike, for they have reached different stages in their careers. The stages have received different names.

First Stage: The Trophozoite.—A trophozoite feeds and grows, and stores up reserve food material; many other animals and plants, besides nourishing themselves for the moment, store up food material for future use. The body of the trophozoite is a single elongated cell surrounded by a thin cuticle, beneath which is a thin layer of clear ectoplasm. The endoplasm forms the mass of the body; it contains many oval granules of reserve nutriment. The ectoplasm contains a layer of fibrils which, like the muscle cells of multicellular animals, are capable of contraction, and perform such movements as the animal exhibits; these fibrils cannot easily be seen. The nucleus is like a vacuole, in which lies an opaque body called the karyosome. When the trophozoite is young, it lies embedded in the protoplasm of a special cell of the earth-worm which is called a spermatoblast; but as it grows it absorbs more and more of the spermatoblast until it becomes too large to be contained within that cell. The mature trophozoite is found free in the cavity of the seminal vesicle.

Second Stage: The Gametocyte.—It has been mentioned that most organisms reproduce their kind by throwing off minute portions of their body, which grow and develop until they resemble the parent. Such portions always contain a nucleus, and are called germ

cells, or gametes. Gametes are of two kinds, male and female, which are usually, but not always, produced by separate individuals. The two kinds of gametes are usually unlike one another in outward appearance, in which case the female gamete is called an ovum, and the male gamete a spermatozoon; contrary to the rule, the gametes of Monocystis are all alike in outward appearance. Whether the two kinds of gametes be outwardly alike or unlike, their behaviour is the same, for they seek one another in pairs, and unite to form a single nucleated cell, which is called a zygote. The single nucleus of the zygote is formed by the fusion of two nuclei, one from each gamete. The formation of a zygote is the first stage in the reproduction of all organisms (except those few which reproduce their kind in the manner called parthenogenetic).

The trophozoite of Monocystis when full grown begins to form gametes, and is therefore referred to as a gametocyte. Just before the process commences, the trophozoites become associated in pairs: they lie side by side and surround themselves with a thin layer of transparent material. They are thus associated for purposes of reproduction within a spherical chamber which is called a cyst. The nucleus of each divides by mitosis (Chap. VIII.) first into 2, then into 4, 8, 16, etc., until a large number of nuclei are formed. The process of division is not easy to see: it proceeds within the endoplasm, and is obscured by the granules. The result of the process however, can be seen without

difficulty, for as soon as the many small nuclei are formed, they move towards the surface of the individual gametocyte which produced them, and lie each within a small portion of clear protoplasm. A gametocyte therefore becomes entirely surrounded by small units of protoplasm, each of which contains a nucleus. These units are the gametes. Changes of this kind occur similarly and simultaneously in both of the associated gametocytes. On their completion, the gametes become detached from their fixed position, and can be seen lying free in the cyst. They then become united in couples, and it is justly assumed that those formed by one gametocyte seek and unite with those formed by the other; the fact, however, is difficult to observe, because the gametes produced by each individual are exactly alike in appearance. As a result of their union a number of bodies called zygotes are formed. Each zygote becomes surrounded by a transparent coat of material called chitin. In this condition the zygote is referred to as a spore, because it leaves the body of the worm and lies in the earth until it is swallowed by another worm. The contents of the spore are saved from the effects of heat and drought by its resistent coat. The spores are oval in shape, with pointed ends like the outline of a boat. The contents of a spore become divided into eight minute elongated bodies which are called sporozoites. The formation of the coat and the division of the contents of the spores takes place within the cyst. Cysts containing ripe spores and others containing ripening spores can be

found without difficulty. Those cysts which contain ripening spores also contain opaque granular material, the remnant of the endoplasm of the parent gametocytes which is expended in nourishing the spores and in providing them with their hard coats.

Third Stage. The Sporozoite.— There are eight sporozoites in every spore, each with a nucleus. When a spore is swallowed by a worm the sporozoites emerge and find their way into a special cell of the worm. They grow and become trophozoites, *i.e.* the first stage of the cycle.

COCCIDIA. The Coccidia are another important group of Sporozoa which are parasitic within the cells of higher animals; they are not found in body cavities, nor do they enter blood cells; they are oval in shape and motionless. Their method of reproduction is completely known, and is the same in principle as that of the Sporozoon which causes malaria in man; it will therefore be described here, although it cannot be studied practically.

The Development of Coccidium schubergi.— The method of reproduction differs from that of Monocystis in two respects. In Monocystis reproduction occurs only by the formation and union of gametes; reproduction of this kind is called sexual. In Coccidium, however, there are two kinds of reproduction, sexual and asexual. Gametes play no part in asexual reproduction. The second respect in which Monocystis and Coccidium differ refers to the outward appearance of the gametes,

In Monocystis they appear alike, but in Coccidium they are outwardly of two kinds, as in the vast majority of animals. Coccidium schubergi lives in the intestinal cells of the centipede *Lithobius forficatus*.

The Trophozoite.—The trophozoite is a motionless oval body which lies wholly within the cell of the intestine of the host. It absorbs nourishment and grows; having reached maturity it undergoes changes for the sake of reproduction. As we have already mentioned, these changes are of two kinds.

Asexual Reproduction (Schizogony).—By this method the parasites become multiplied within the body of the centipede, so that more and more of the cells of the intestine become infected until five days after the entrance of the first parasite, when most of the intestine is destroyed and the host begins to die. When the trophozoite is mature its nucleus divides many times; subsequently the protoplasm also divides, so that each division contains a portion of nucleus. The dividing trophozoite is called a schizont, and becomes resolved into a large number of elongated bodies called merozoites. The merozoites part company, fall into the gut of the host, and, by means of their pointed ends, penetrate the other healthy cells which line the gut; after penetrating a cell, they grow rapidly, and become mature trophozoites, which again become schizonts. The events therefore succeed one another in a cycle which is repeated again and again until few healthy cells remain in the centipede's intestine; other events then occur.

Sexual Reproduction (Sporogony).—In this process resistent spores are formed which pass out of the centipede and into the earth, where they may be eaten by other centipedes. Spores are formed, as in Monocystis, by the union of gametes, which are of two kinds, large macrogametes and small microgametes. The gametes are produced in the following way. When the centipede is becoming exhausted by the repeated asexual cycles, the trophozoites become altered in appearance: some of them become macrogametes, others produce a number of microgametes. A macrogamete is a large bean-shaped cell; it is merely an altered trophozoite. A microgamete is a minute filamentous body which moves actively, being impelled by two lashing threads or flagella, which are attached at either end of it. The microgametes are formed much in the same way as merozoites, by repeated divisions of a trophozoite, which is in this case called a gametocyte. An active microgamete moves towards the nearest macrogamete, which is usually lying passively in the gut of the host, and becomes fused with it. Thus the body called a zygote is formed, from which the sporozoites are derived. The zygote becomes covered with a tough, chitinous membrane, in which condition it can survive outside the body of the centipede. The zygote is a single cell with a single nucleus formed by the union of two nuclei, which may be called male and female: the nucleus of the macrogamete is called the female nucleus, the other, which was contributed by the microgamete is the male nucleus.

The nucleus of the zygote divides into four pieces, each of which becomes surrc nded by a cyst wall, and further divides into two sporozoites. The zygote therefore resembles that of Monocystis in that it is covered with a tough, resistant wall, and breaks up into eight sporozoites, but in Coccidium the sporozoites are formed in couples. When a centipede swallows a zygote along with its food, the sporozoites issue from the cyst, enter the cells of the intestine and become mature trophozoites, which undergo schizogony. The foregoing description is of the main facts of the reproduction, but many other important details are known, which have not been mentioned.

A union of two unlike gametes, the one small and motile, the other large and passive, occurs in the reproduction of all the higher animals; this sexual method of reproduction has long been known in them, but that a similar process occurs among the Protozoa is a more recent discovery.

HAEMOSPORIDIA.—In this group the trophozoite is a parasite within the red blood cells of warm-blooded animals. The most important of them are Plasmodium and Laverania. which cause malarial fever in man. The life-history of these parasites is essentially like that of Coccidium. In it there are two separate cycles. The asexual cycle (schizogony) occurs within the blood of man. The malarial parasites use the red corpuscles of man in exactly the same way as Coccidium uses the intestinal cells of the centipede; in other words, as a

sporozoite they enter a red blood cell and feed upon it as a trophozoite; when full grown they divide into a number of merozoites, which disperse and infect other healthy blood cells, just as the merozoites of Coccidium infect other healthy intestinal cells. This cycle of schizogony is repeated several times; at each dispersal of merozoites the infected man gets an attack of ague. The asexual cycle of Plasmodium malariae occupies seventy-two hours, and causes quartan ague; that of P. vivax occupies forty-eight hours, and therefore causes tertian ague. The trophozoites of these parasites are amoeboid; in this respect they differ from Coccidium. The method and meaning of the sexual cycle is essentially the same as in Coccidium. By schizogony, Coccidium cannot pass from centipede to centipede, neither can the malarial parasite pass from man to man. Only by the sexual cycle (sporogony) can a fresh host be infected. In both cases the sexual process results in the formation of sporozoites; in Coccidium these lie in the earth for a time, and are therefore confined within a resistent cyst. In the malarial parasite the whole sexual cycle is passed in the body of a mosquito. Some of the trophozoites in a man's blood become gametocytes. When the mosquito sucks the blood of an infected man, the gametocytes pass with the blood into the stomach or mid-gut of the mosquito, where unequal gametes are formed and unite to produce zygotes, which are soon after found projecting from the outer surface of the organ. Within each zygote a large number of sporozoites

ed, which leave the zygote cyst and find into the salivary glands of the mosquito and to infect a healthy man. The details of this e usually treated as part of Pathology.

CILIATA

The Ciliata are Protozoa which possess cilia. Cilia are delicate threads of protoplasm which are attached to the surface of a living body, as our own hair is attached. Cilia are outgrowths of the protoplasm of living cells, and are in motion throughout the life of the cells which bear them. The movement of a cilium is like that of a man who bows rapidly, profoundly and repeatedly, always in the same direction, and becomes more slowly erect between each bow. A cilium is not independent in its movements. Cilia are placed in rows, those in a row move one after another, so that the movement in a ciliated surface looks like the waves which pass over a field of corn when the wind blows upon it. Cilia only occur on surfaces which are in contact with water, or covered by a film of moisture. The result of a vast number of cilia moving in the manner described must be either a flowing movement in the water, which is compelled to pass over the ciliated surface, or a movement of the ciliated body through the water, like a boat which is rowed by oars. The production of currents in water by means of cilia is frequent in the animal kingdom. Nearly all animals, except Arthropods, possess cilia on

some part of the body; in man the tubes of the lungs and some other parts of the body are lined by cilia, which cause moisture to flow over their surface. Minute animals which live entirely in water often use cilia for progression. The ciliated Protozoa move in this manner. The Ciliata are found in infusions, in fresh water, and as parasites within the cavities of Metazoa. Like the Sporozoa, they are covered with a thin cuticular layer which prevents amoeboid movement; in nearly all of them this is pierced by an aperture—the mouth. The nuclear apparatus is two-fold; there is a large nucleus called the macronucleus and a small micronucleus.

PARAMOECIUM.—This Protozoon, which is often found in infusions, is distinctly visible to the naked eye. It is very active in its movements, and is therefore rather difficult to examine; it must, however, be carefully observed in the living state. Place a drop of infusion containing Paramoecia upon a slide and cover it, supporting the cover slip by means of another. Paramoecium is ovoid in shape, with somewhat pointed ends, one end being rounder than the other; the body is covered everywhere with cilia, which are arranged in longitudinal rows, and give to the animal a striped appearance. On one side of the middle of the body is the mouth; this is an oval aperture in the cuticle which elsewhere covers the whole body. The mouth is the opening of a funnel-shaped depression or vestibule, which is surrounded by the soft inner protoplasm. In the wall of the vestibule is a row of cilia, which compel grains of food material to

enter the mouth. The protoplasm of the body consists of an outer clear ectoplasm and an inner granular endoplasm. The ectoplasm contains a large number of fine elongated sacs, which point towards the surface; minute rigid threads are shot out from these sacs through the cuticle. These are weapons of offence, and are known as Trichocysts. Within the endoplasm is a large oval macronucleus and a smaller micronucleus. There are two contractile vacuoles, which usually open upon the side opposite to the oral surface. Food vacuoles are formed at the apex of the vestibule, and circulate through the endoplasm. When a contractile vacuole collapses, a stellate appearance can be seen in the protoplasm around it, as though fluid were streaming along lines radiating from the diminishing vacuole.

Reproduction.—One Paramoecium becomes two by simple transverse fission, without loss of material in death. This is preceded by division of both the macronucleus and micronucleus. Since Paramoecia are visible to the naked eye, the process of reproduction can be observed and controlled without much difficulty, and many interesting experiments have been performed upon this Protozoon. A Paramoecium was placed in a small capsule until division was observed; the halves were then transferred by means of a pipette to two separate capsules, and each supplied with food (bacteria). The halves grew and divided in their turn. In this way a Paramoecium was seen to divide five times in

twenty-four hours, giving rise in that time to thirty-two progeny.

Conjugation.—Under certain conditions Paramoecia conjugate, that is to say, two approach one another and become united for a short time; in this union the soft protoplasm of both becomes continuous through the conjoined mouths, and an interchange of nuclear material takes place between the two. Preliminary to this change, certain events take place in the nuclei of both individuals; the macronuclei swell up and become dissolved in the endoplasm of the body; the micronuclei divide into four (eight in some species); of these four, three also disappear; the remaining fourth part divides into two. In each of the pair one half of this nuclear portion remains where it was formed, the other passes through the conjoined mouths into the body of the partner. After this exchange of nuclear portions the animals separate. In each individual the two portions of nuclei, the one its own the other borrowed, fuse together; from the resultant a new macronucleus and a new micronucleus are formed.

Now, as to the necessity of this process, it has been found that, after fission has occurred about three hundred times, the progeny deteriorate, and if they are prevented from conjugating by artificial separation they will cease to divide and ultimately die, but if in this deteriorated condition they be allowed to conjugate with fresh stock their vigour is restored, and they begin again to reproduce by fission. The effect of conjugation has

therefore been spoken of as rejuvenescence. It has been found that the necessity for conjugation can be postponed artificially by supplying the Paramoecia with particular forms of nourishment. It seems, however, to be doubtful whether the necessity can be altogether abolished by these means.

NYCTOTHERUS.—Paramoecium cannot always be obtained. Infusions may be prepared time after time, with the result that other kinds of ciliated Protozoa appear which are smaller and less suitable for observation. A large Protozoon called Nyctotherus may nearly always be obtained from the intestine of the common cockroach. Nyctotherus is an oval and flattened disc covered everywhere with cilia. There is a deep oral groove on one side, which is continued as a transverse groove across one of the faces of the disc. The margin of this groove is fringed with a row of cilia, at the base of which is a narrow membrane. The transverse groove ends in a vestibule which dips into the endoplasm. The macronucleus is large and oval, the small round micronucleus lies by its side. There is a special and permanent excretory pore which opens into a short passage terminating in the contractile vacuole. The excretory passage always points towards the side of the body upon which the oral groove lies. Conjugation may often be seen in this Protozoon.

VORTICELLA.—Vorticellae can always be obtained, and are easily examined. They are commonly found attached to weeds in fresh water; they also appear in infusions.

Although they are convenient to examine, the details of their structure are not very easy to see. By studying them carefully, the student will come to know the advantage of looking at microscopic objects from all sides, with varying focus and light supply. The body of Vorticella is shaped like a bell; in the place of the handle of the bell is a long contractile stalk, by which the Protozoon is fastened to some object, usually a floating weed, sometimes a moving animal, such as a mosquito larva. The whole body is covered with cuticle. Within the margin of the bell is a groove which appears to be covered by a thinner and more flexible cuticle. This groove is called the peristome; it surrounds a smooth circular disc which is placed as though it were a cover or lid for the bell. When the animal is fully expanded, the margin of the bell is turned outwards and downwards. At one point upon the peristome is the opening of a pit called the vestibule. In the fully expanded condition the mouth of the vestibule can be seen at the highest part of the peristome. Situated upon the peristome, and completely encircling the disc, is a row of large cilia called adoral, and a row of small cilia called paroral. The adoral row is placed close outside the margin of the disc; it is therefore arranged as a ring, but this ring is not complete, for it is broken at the vestibule, where one end of it lies outside and below the other. The outer end of the ring is not a true termination of the ciliary row, but is the spot where the row dips abruptly downwards into the vestibule; this can be seen

without much difficulty, but it is less easy to see that this vestibular row of cilia ascends in the opposite wall of the passage, and becomes continuous with the inner end of the adoral row. The paroral cilia are about half the length of the adoral cilia, and are placed outside them in a similar row. When the Vorticella is fully expanded, a very delicate flap of membrane is thrust out of the vestibule, which helps to direct the food particles into the mouth. The tips of some of the adoral and vestibular cilia can be seen brushing the inner side of this undulating membrane, as the structure is called. The substance of the body consists of a broad clear ectoplasm and granular endoplasm. The food vacuoles are large, and can be seen to circulate. It is a good plan to introduce particles of carmine into the water. If this has been done, it will be seen that each vacuole contains not one, but several grains of the pigment. When several grains of food material have collected at the bottom of the vestibule, they become enclosed within a vacuole which becomes detached from it. A succession of vacuoles, formed in this way, follow one another along a definite course through the endoplasm, and are finally rejected into the upper end of the vestibule at a particular spot called the anus. The contractile vacuole lies between the disc and the vestibule, and opens into the latter. The macronucleus is a long bent rod, the micronucleus is small and round. To see the nuclei properly, take a small tuft of Vorticella attached to a weed, and dip it into acidulated

methyl green for five minutes, wash it in one per cent. acetic solution for a minute or two, and examine it under the microscope in a drop of the latter solution. This simple method of staining is most useful, and may often be used to render nuclei conspicuous.

Reproduction and Dispersal.—A Vorticella may form a third ring of long cilia, which surrounds the body close above the stalk. The bell then becomes detached, and with the help of these aboral cilia swims away through the water. Vorticella may also become encysted; hence its appearance in infusions. Reproduction takes place by longitudinal fission, as a result of which two individuals may sometimes be seen attached to the same stalk side by side. One of them will become detached, and by means of aboral cilia will swim away and settle down in another place upon a new stalk.

FLAGELLATA

The Flagellata are active unicellular organisms which are covered externally with a cuticle, and are provided with one or more flagella. A flagellum is a thread of protoplasm, and resembles a very long cilium; it is used to propel the animal through the water. Many flagellate organisms contain the green substance called chlorophyl which occurs commonly in the vegetable kingdom; those that are so endowed are able, with the help of sunlight, to prepare starch for their own nutrition out of the

carbon dioxide which is dissolved in the water around them. The cuticle of some Flagellata is perforated by a mouth, through which the animal obtains food. Others have no mouth, and live either in the nutritive fluids of other animals, or they support themselves wholly as plants by means of chlorophyl. Some, such as Euglena, which may occasionally be found in the fresh waters of India, have a mouth and are also provided with chlorophyl. Among the Flagellata, therefore, are organisms for which the terms animal or plant cannot be used with certainty. Those which have a cuticle composed of the vegetable material called cellulose, and have chlorophyl but no mouth, are usually classed as plants; the others which do not possess these things are looked upon as animals; but a line cannot be drawn clearly between the two groups, because forms such as Euglena have both methods of nutrition. It is a most interesting fact that the sharp line which can otherwise be drawn between plants and animals becomes broken down among simple organisms.

Herpetomonas.—Many flagellate Protozoa are parasitic in the higher animals; some of them are a cause of disease in man. Herpetomonas is very common in the intestine of common house-flies; it is not confined to a particular species, but may occur in any small muscid flies, such as are to be found upon the laboratory windows. It will rarely be necessary to examine as many as five flies before finding the parasite. Kill the flies with chloroform, place one of them upon a slide in

a drop of salt solution, snip the side of the abdomen with scissors and pull off the hinder end of it, so that the viscera are exposed in the salt solution. With needles separate the abdominal viscera from the rest of the body, which should be removed from the slide. If eggs are present, they will be the most conspicuous things among the viscera; they are elongated white bodies which are easily visible to the naked eye; they also should be removed from the slide. The intestine, which remains is a semi-transparent tube, it should be cut across in two or three places by pressing upon it with a sharp knife, so that its contents may flow out. Cover it with a slip and examine under the high power of the microscope. The contents of the intestine will be seen flowing out from the cut ends, and with them the parasite. Herpetomonas is a slender transparent organism which varies from twenty to thirty micro-millimetres in length, *i.e.* a little more than three times the diameter of a human red blood corpuscle; sometimes they are present in such numbers that the intestine seems to be nearly choked with them; although transparent and small, they are conspicuous because of their active movements. They often struggle to keep their position against the current as it flows from the intestine; a Protozoon may therefore behave in exactly the same way as one of the higher animals in response to a particular circumstance. If a fish or other swimming animal finds itself in flowing water, it also will swim against the current so as to keep its position. This fact becomes interesting when we

consider the great anatomical difference between a fish and a Protozoon.

In order to see the structure of Herpetomonas it must be stained in a particular way. A small drop of the salt solution containing many of the parasites should be dried upon a slide, and stained by Giemsa's method. They should be examined with the highest power available. The body of Herpetomonas is slender, the breadth being only about one-tenth of the length; it is tapering towards the extremities. One end is less pointed than the other, and gives attachment to one or two long flagella. It seems to be a matter of doubt as to whether one or two flagella are normally present; some authors say that one is the normal number, and that those which show two are undergoing reproductive fission. On the other hand, the appearance of two flagella is so frequent that it may be regarded as a normal feature, on the supposition that the appearance of a single flagellum is false, and due to two flagella clinging together in their whole length. The flagella are usually twisted in two or three coils; when they are straight they are somewhat longer than the body. The body is stained blue; in the middle of it is a large oval nucleus, which is nearly as broad as the body itself, and is stained red; this is called the trophonucleus. A short distance from the flagellated extremity is a small deeply stained body called the kinetonucleus; between it and the extremity is an oval unstained area, which appears to be a vacuole. A fine thread can be seen uniting the kinetonucleus with the bases of the flagella.

Individuals which are undergoing longitudinal fission can often be seen; if a number of them be carefully examined, it may be noticed that in some of them the flagellum appears to be single, even when the division of the body is nearly completed; this is the strongest reason for supposing that the appearance of a single flagellum is deceptive.

Trypanosoma is a flagellate Protozoon which resembles Herpetomonas in many ways; it differs from it in possessing an undulating membrane which is attached along the whole length of the body, and somewhat resembles in function the fin of a fish. Trypanosomes are found in the blood of vertebrate animals of all kinds. They do not penetrate the corpuscles of the blood, but swim freely in the fluid. They are often harmless, but they may be the cause of fatal disease, both in man and animals. They are usually passed from one host to another by the agency of a third animal, usually an insect, which sucks the blood of the vertebrate for its food. Another interesting method of transmission occurs in certain Flagellates, which are parasitic, in insects; some of the parasites migrate from the intestines of the host and find their way into its eggs. When therefore the young insect which develops out of the egg enters upon its life, it is already infected with a parasitic Protozoon.

The usual method of reproduction in all parasitic Flagellates is by simple fission, as in Herpetomonas. It is well known that other more complicated sexual

methods occur, but at present our knowledge of them is doubtful, and they cannot be spoken of except at great length. It is however known that certain minute cells called "Leishman-Donovan" bodies may occur as parasites in the tissues of man; they can always be found in the disease Kala Azar, and in Oriental sore. If these bodies be cultivated in certain fluids, flagellate Protozoa arise from them which are remarkably like Herpetomonas in appearance.

PLATE II.

SPOROZOA

A. The life cycle of Coccidium (diagrams after Schaudinn).
The parasites are lying within the intestinal cells of the Centipede 1 5 schizogony, 6 9 formation of gametes (*f.* microgm, *m.* microgm), 10 the zygote, 11 13 formation of sporozoites.
B H represent stages in the life history of Monocystis from the seminal vesicles of the earth worm.

B An adult Monocystis

C. Two individuals associated for reproduction in a cyst.

D. Formation of gametes

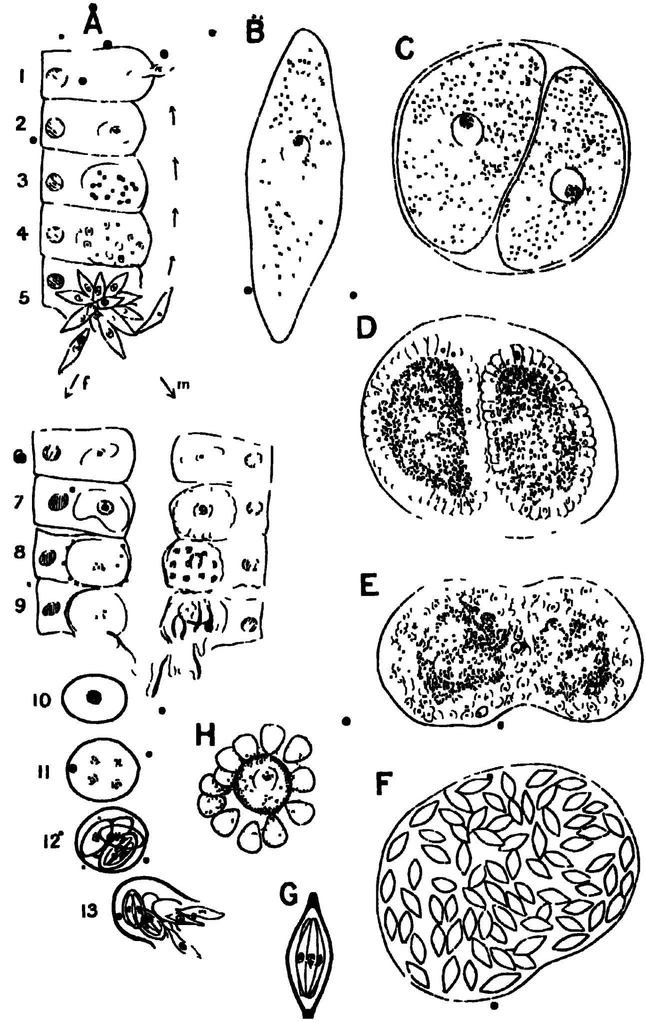
E. Union of gametes

F A cyst full of spores

G. A single spore containing 8 sporozoites

H. A young Monocystis within a spermatoblast.

B—F × 150. G × 2000. H × 900 (approx.)



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CHAPTER II

PORIFERA—COELENTERATA

It has been mentioned that the bodies of all animals other than Protozoa are composed of a large number of cells which appear to be distinct from one another. However, the body of a multicellular animal must not be regarded as a colony of separate cells, each strictly comparable in itself to the body of a Protozoon, for the cells of a Metazoon are in function and appearance of different kinds, and are dependent on one another for the performance of their several duties. We have seen that the body of a Protozoon, although consisting of a single cell, can perform all the functions which are common to animals, such as to move, feed, excrete and reproduce; in a Metazoon the several functions are distributed among the different kinds of cells. The question as to how the several kinds of cells are related to one another, and to the conditions of the outside world, is dealt with by the physiologist. One of the most important means by which the several parts of a complex body are made to work in concert lies in the invisible but demonstrable bodies called internal secretions. These are substances which may be formed

in a particular part of the body and produce effects in other parts, or upon the body as a whole. It is largely by their influence that the several parts of a complex body work in unison, and an individuality is conferred upon the whole. There is one group of animals, namely, the Porifera, or sponges, in which the cells are so loosely connected that the body has been regarded by some as a colony of Protozoa rather than as an individual Metazoon. The general opinion, however, is that a sponge constitutes an individual body comparable to that of any other Metazoon. Sponges are usually plentiful in tanks in India, and as they illustrate in a simple manner such important animal functions as phagocytosis, symbiosis, and secretion, they should be examined by the student. Sponges of the kind found in fresh water are, for sponges, somewhat complex. The student must know that there are very many different types of sponges, and a proper understanding of the whole group can only be obtained by examining several types, especially the simple ones.

SPONGILLA

Spongilla is found in tanks adhering to submerged objects; it is variable in form. It occurs as nodular masses, which may be as much as a foot in diameter; and such masses are sometimes attached to the sides of the submerged steps of a tank, but more commonly they measure two or three inches, and are found encircling

a sunken branch of a tree, or the stem of a water-plant. Spongilla may form a flat encrusting growth, perhaps upon a submerged stone. When found, it is not always in a fresh condition. The structure is best seen in living and vigorous specimens. The best examples for examination are very young specimens about the size of a pea, which are sometimes found adhering to small floating plants. Some sponges, especially small ones which grow in sunny places, are green, others are of a grey colour. In general appearance Spongilla calls to mind the well-known sponge of commerce: the surface is covered irregularly with minute spiney projections, the ends of needle-like bodies which are embedded within the sponge, and are called spicules. Two or three circular apertures called oscula can be seen upon the surface; these are the openings of passages which lead deep into the substance of the sponge. In the largest sponges the oscula may be so large as to admit the finger. Besides the oscula, the whole surface is covered with minute round apertures, which are scarcely visible to the naked eye; these are the ostia. During the life of the sponge a current of water enters through all the ostia and pours out of the oscula.

The sponge as a whole is built up of two kinds of substance, the one forms the skeleton or framework, and is composed of a large number of objects resembling needles of glass. These needles, or spicules, are bound together in bundles or strands which are united in the characteristic manner commonly called "spongy." The

other kind of substance is the living material protoplasm, which is arranged as units or cells among the meshes of the skeleton, and covers the whole outer surface of the sponge.

THE SKELETON.—The stability and firmness of a sponge is due to its skeleton. For the examination of this supporting framework it is well to choose a specimen which is not very young. It is usually easy with a sharp knife to cut from an old sponge a slice of about one-eighth of an inch in thickness, which will not readily fall to pieces. Such a slice should be removed by two parallel cuts at right angles to the surface, so that one edge of the slice will represent the surface. The slice should be soaked for a few minutes in strong nitric acid. The material of which the skeleton is composed is silica, a glass-like substance, which is not in the least affected, though all else is dissolved by the acid. The slice should be washed in water and examined under the low power. A number of strands are seen, the largest of which are directed mainly towards the surface, although not with great regularity; they are bound together by lesser strands which cross one another in any direction. Between the strands are open spaces of irregular shape, some being roughly spherical. Before the acid was applied, protoplasm occupied the spaces and clung to the strands of the skeleton. It is easy to see that the strands are bundles of separate bodies which resemble needles of glass; these are called spicules; they are smooth and pointed at both ends

It is characteristic of the class of sponges to which Spongilla belongs that the spicules should lie only in one axis; they are therefore called monaxons. In some other classes of sponges each spicule is developed along more than one axis, which are placed in relation to one another with mathematical accuracy. The spicules of the hexactinellid sponges have six straight branches, which grow out from a central point in such a way that each branch is exactly at right angles to its neighbours. The hexactinellid sponges form a large group, each member of which produces its spicules with the same precision; they mostly live in the deep sea. The spicules of Spongilla are united by spongin, a substance which somewhat resembles silk. It occurs in Spongilla as a kind of brownish glue, which cements the spicules together. It also occurs as threads, which are woven among the spicules and bind the whole mass to some fixed object. Besides the large monaxons two other smaller kinds of spicules occur, which are called flesh spicules. One kind is curved and spiny, and less than a quarter the length of the monaxons, the other kind is smaller still and irregularly star shaped. The spicules are secreted by living cells of the sponge, that is to say, certain cells of the sponge can collect some of the minute quantity of silica which is dissolved in the water, and render it insoluble, so that it appears within the cell as a rod of solid glassy material. We cannot explain why any particular cell should give rise to spicules of a certain shape.

THE LIVING MATERIAL.—The protoplasm of a sponge consists of a vast number of separate cells which are of several different kinds. The various kinds of cells can be distinguished by the student, but their position relative to one another and to the skeleton can only be elucidated by means which are beyond the powers of a beginner. Protoplasm occurs externally as a thin sheet which covers the outer surface of the sponge, and internally as a vast number of cells which lie among the spicules, some in a definite position, others indefinitely.

The Derma.—The outer covering is called the derma; it is rarely complete in an old sponge. In order to see it in the living state, place a sponge, preferably a very small one, in a watch-glass of water, and examine the side of it under the low power of the microscope, adjusting the focus until a clear view of the surface is obtained. The mass of the sponge is opaque, but there appears to be a transparent outer layer which covers the whole to a depth of two or three millimetres. This appearance is produced in the following way. The derma of the sponge is a thin transparent membrane of living protoplasm, which is lifted from the general mass of the sponge by the ends of those spicules which are at the surface. The arrangement of this dermal layer calls to mind a large tent which is raised above the ground by a number of tent poles of unequal length; in the sponge the derma represents the canvas of the tent, while the spicules represent the tent poles; the space which is

between the derma and the mass of the sponge is called the subdermal cavity.

We will now consider the structure of the derma. A collection of cells is called a tissue. Tissues are of many kinds, the derma of a sponge is of the kind of tissue called a pavement epithelium. Epithelium is the name given to a number of cells lying side by side so as to form a flat sheet, which may cover a surface or line any hollow space within an animal. In a pavement epithelium the cells are flat, and their edges are in contact like the stones in a pavement. It is hardly possible to see the individual cells of the derma of Spongilla in the living condition. The derma is perforated by small circular apertures, or ostia, which are clearly visible under the low power of the microscope. When they have been observed, a little powdered carmine should be added to the water in which the sponge lies. The grains of carmine appear as dark specks in the water, which drift slowly towards the surface of the sponge and enter the ostia very rapidly. This experiment demonstrates the method by which a sponge obtains its nourishment. The current of water which enters the ostia is set up by certain cells within the sponge which are provided with flagella. The smaller kinds of spicules will usually be seen lying in the derma, especially the curved spiny variety. The student can examine the individual cells of the derma when they are separated from one another by a method to be described in the next paragraph, but they can also be seen in their natural position without much difficulty

after the following treatment. Place a small living sponge in strong spirit, and leave it there for not less than five minutes. With a sharp knife shave off a small portion of the surface, stain and mount the fragment in Canada balsam, and examine it with the high power.

The Separated Cells.—Having examined the derma as a whole, we will now observe its component cells after they have been separated from one another, as well as the other kinds of cells which occur in the deeper parts of the sponge body. For this observation a young growing sponge, a green one if possible, should be placed in a capsule of water, to which is added a small quantity of pure insoluble carmine; after about an hour it will be found that there is very little carmine in the water, for the sponge has absorbed it and become of a deep carmine colour; if this does not occur the sponge is resting or dead, and is unsuitable for examination. A small portion of the coloured sponge should be cut off and placed in acetic methyl green solution for three minutes. It should be taken out and placed in one per cent. acetic acid for a minute; it is then ready for examination. Place it upon a slide, break it up with needles in a clear drop of the acetic solution, cover and examine under the highest power of the microscope.

We may now consider the various kinds of cells under three categories, the dermal cells, the gastral cells, and the amoeboid cells. The dermal cells and the gastral cells form epithelia, which have a fixed position in the

sponge body; all cells other than these may be called amoeboid, because they have no fixed position, but it must be clearly understood that these amoeboid cells are of several different kinds, which perform different duties. They are here classed together merely because they have no fixed position in the sponge body.

The Dermal Cells.—The largest cells which can be seen on the slide are the dermal cells. They are of a shape which is between square and oval with an even border, and are stained a very faint green colour. In the centre of each there is a nucleus, which is stained much more deeply than the protoplasm; within the nucleus is a round body called a nucleolus. The dermal cells are numerous or scanty according to circumstances, for they may become detached from their natural position in the staining process. They are larger than any of the other cells, and show the minute structure of protoplasm very clearly when stained in the manner described. They show that protoplasm is not clear like glass, but has the appearance of a net with irregular meshes. There appear to be two substances in protoplasm, comparable to the thread and mesh of a net; the former is denser than the latter, and stains more deeply; the latter, which is believed to be the more fluid, does not become coloured by the stain. The opinion of observers differs as to the interpretation of this reticular appearance. Some suppose that protoplasm is in structure like a foam, such as can be made by blowing air into soapy water; except that the interstices of the foam are

occupied by a fluid substance, in the case of protoplasm. The exponents of this view hold that the appearance of threads in the apparent network is due to the walls of vacuoles, which are seen in optical section. Others suppose that the denser material is a true network of threads which lie in all directions and unite irregularly with one another; according to this view the denser protoplasm somewhat resembles in its arrangement the twine in a tangled heap of fishing net. These remarks apply to the structure of protoplasm in general: they have no special reference to the epithelium cells of Spongilla, except that these bodies when stained with methyl green show the reticular appearance in a most satisfactory manner.

The nuclei of the epithelial cells should be looked at carefully. A nucleus is a spherical body bounded by a thin but distinct outer wall, from which threads can be seen passing irregularly towards its centre; these threads unite with one another to form a network, which is much plainer than that of the protoplasm, because it is stained more deeply. Among the threads is a small round body which also is stained deeply, and is called the nucleolus. Because the chief material of the nuclear net becomes stained very deeply, it is called chromatin. Every cell of an animal or of a plant contains a nucleus which is composed principally of chromatin.

The Gastral Cells. These cells are of a peculiar type, and are sometimes called 'collar cells.' In shape they are irregularly ovoid or cylindrical; they stain

more deeply than the epithelial cells, and appear granular. At one end a funnel-like collar is attached, out of which protrudes a long flagellum. The nucleus is larger than that of the epithelial cells. The collar and flagellum are delicate structures of transparent protoplasm, and are not very easy to see. Some observers have found that, in a sponge which has been fed recently (since an hour) with carmine, these cells are full of ingested grains; this is not always the case.

Amoeboid Cells.—These are of many kinds, which perform different functions. The most noticeable, under the circumstances of our experiment, are certain cells which contain many carmine grains within their substance. As the carmine grains appear black, or nearly so, these cells can be seen at a glance. They are variable in size, and irregular in shape, being provided with outgrowths or pseudopodia; the nucleus may or may not be obscured by the carmine. They have taken the carmine grains as food into their substance by means of their pseudopodia, just as an Amoeba takes its food. Cells which behave in this way are called Phagocytes; they are found even in the highest animals, and are of the utmost importance in the economy of the body. In sponges their function is mainly nutritive, to take food, to digest it, and probably to distribute it. In man and the higher animals, the chief function of the phagocytes is to devour intruding organisms, such as bacteria, which may cause disease.

Secreting Cells.—It is the work of certain cells called

scleroblasts to secrete the spicules. A spicule first appears as a minute filament of silica within one of these cells; it increases in size until it is larger than the cell, which becomes extended so that its protoplasm still covers the growing spicule, and continues to add silica to it. In the higher animals all structures such as teeth, hair, shells, etc., are formed by the secretive activity of living protoplasm.

Cells containing Algae.—Many of the cells contain round bodies of a yellowish-green tint, which is quite different from the bluish green caused by the stain. These bodies are unicellular plants or Algae, which are living with the sponge in a state of symbiosis. The colouring matter which they contain is chlorophyl, the green pigment of plants. The term symbiosis is used to describe a kind of partnership which sometimes exists between two organisms of different kinds, and is such that both organisms receive some benefit from their mutual relation. Symbiosis may occur between two plants, between two animals, or between a plant and an animal, as in this case. Chlorophyl has the power of making starch from carbon dioxide and water. Without sunlight chlorophyl cannot be developed, nor if it be developed can it exercise its power in the dark. The colour of a green sponge is due to the Algae. It has been mentioned that sponges are by no means always green, but that the green ones are always found in sunny places. If, in our experiment, we had used a solution of iodine instead of methyl green, many of the cells,

especially those which contain Algae, would be seen to contain grains of a purplish-black colour. These are grains of amylum, a substance allied to starch which has been formed by the chlorophyl of the Algae. The sponge uses this material for its nutrition; the Algae no doubt receive some compensatory advantage from the sponge, for it has been shown that they grow independently in the surrounding water, and that they invade the sponge from without.

Other Cells.—There are other kinds of cells to be seen, but, unlike those mentioned, they do not possess particular features by which the beginner can easily recognize them. There are some important cells called Archaeocytes which are concerned in the growth of the sponge and in the reproduction.

THE ARRANGEMENT OF THE INTERNAL CELLS. — The arrangement of the cells other than those of the derma cannot easily be seen in Spongilla. An intricate mixture of silica and protoplasm is difficult to examine by ordinary methods. Our knowledge of the subject however, has been made clear by special methods, as well as by consideration of the structure of other kinds of sponges which are more easily investigated. The derma forms the roof of the subdermal cavity, the ostia open into this cavity. The floor of the subdermal cavity is scattered with holes, which are the mouths of channels leading deep into the substance of the sponge among the strands of the skeleton. These channels contain water which is constantly in motion. The channels are lined

by pavement epithelial cells similar to those of the derma. There are two systems of channels, called inhalent and exhalent. The exhalent channels become united together, just as the twigs and branches of a tree become united in the stem. The main channels which represent the stem of the tree open at the oscula. The openings of the inhalent channels are in the floor of the subdermal cavity. The two systems are placed in communication with one another by means of very small spherical spaces called the gastral chambers. The gastral chambers are lined by flagellated or collar cells, which are arranged side by side as an epithelium. Each gastral chamber communicates by one large opening with a channel of the exhalent system, and by many smaller openings with channels of the inhalent systems, the two systems are therefore in communication with one another through the gastral chambers. The flagellated cells which line the chambers compel water to pass from the inhalent channels into the exhalent channels, and set up a constant circulation throughout both the systems.

Reproduction.—Sexual reproduction occurs in all sponges, but the process is not easy to observe in Spongilla. Ova and spermatozoa are produced from certain cells within the body of the sponge, and passing out in the exhalent current, undergo union and development in the water. Freshwater sponges have a special asexual method of reproduction by means of bodies called gemmules. These bodies, which, to the naked

eye, closely resemble fig-seeds, are found embedded in the substance of most freshwater sponges. Some of them should be cleaned with nitric acid, dehydrated and mounted in Canada balsam. A gemmule consists of a spherical, thick-walled shell surrounding a central cavity which communicates with the exterior by a cylindrical tube. The cavity contains a minute protoplasmic body or bud, which, under favourable conditions, may pass out through the tube and develop into a new sponge. The structure of the shell of the gemmule is different among the various kinds of sponges. In S. carteri, which is common in India, the shell consists of an inner layer of horny material surrounded by a thick, outer crust of the same material, which is formed like a bees' honeycomb. A few monaxon spicules cling to the outer wall. In other species, various kinds of spicules take part in the composition of the walls of the gemmule. Sponges are disseminated by means of the gemmules, which are very resistant to drought.

PLATE III.

SPONGILLA.

A. Spongilla. 1. osculum.
B. Superficial part of a small living sponge. 1. monaxon spicule; 2. flesh spicule; 3. ostia; 4. opaque inner substance.
C. Spicule developing within a scleroblast.
D. Gastral cell with collar and flagellum.
E. Dermal cell, showing reticular structure of protoplasm.
F. Amoeboid cells. 1. contains spherical algae and amylum granules; 2. and 3. contain ingested particles of carmine.
G. Skeleton, cleaned with nitric acid.
H. Diagram of a sponge. 1. inhalent passage; 2. exhalent passage; 3. gastric chambers.
J. Two gemmules—one from the side, the other from above.
A × ½. B, G, J × 50. C—F × 450 (approx.).

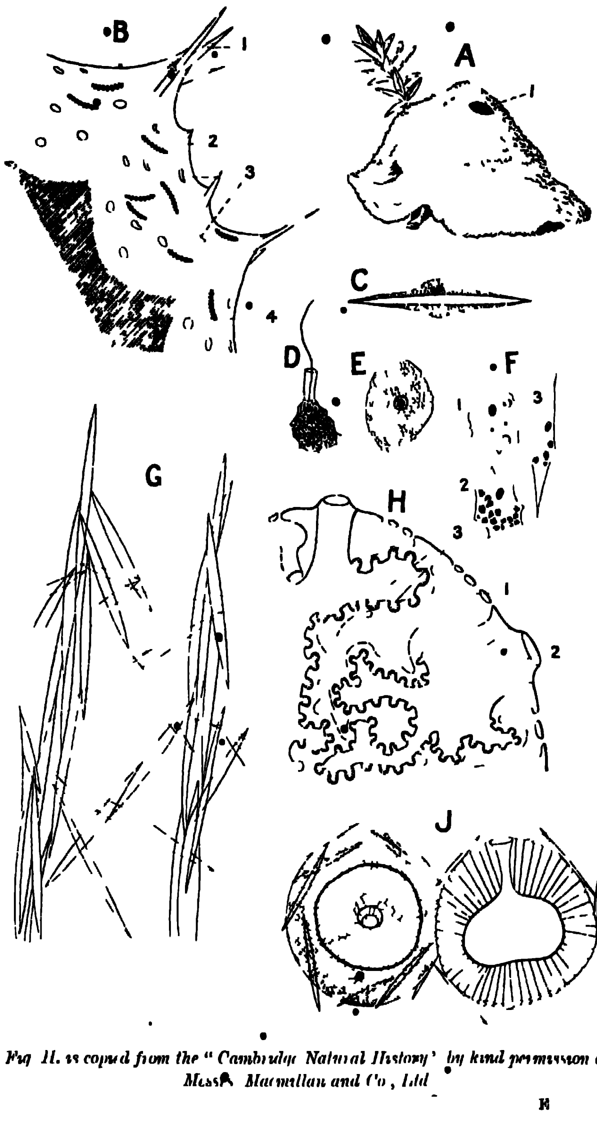

Fig 11. is copied from the "Cambridge Natural History" by kind permission of Messrs Macmillan and Co, Ltd

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COELENTERATA

In multicellular animals other than the sponges the cells are combined in a more definite manner, either in layers as epithelia or in other ways to form the organs of the body. In the Coelenterata, the cells are arranged in two layers named ectoderm and endoderm. The ectoderm is the skin which covers the whole outer surface of the animal, the endoderm lines a large cavity which is within the body and is called the enteron or gut. The ectoderm and endoderm become continuous with one another at or near to the only aperture of the body; food is taken into the gut through this aperture, which is the mouth. There are no organs between the ectoderm and the endoderm. In many Coelenterates, the two component layers are almost in contact with one another, like the brickwork and plaster of a wall; they are, however, separated by a thin layer of structureless gelatinous material called the mesogloea. Sea anemones, coral polyps, and jelly fish are Coelenterates. They are mostly inhabitants of the sea. In the jelly fish the ectoderm and endoderm are widely separated by an abundant mesoglœa.

HYDRA.—As an example of a Coelenterate we will examine Hydra, a small animal which is common in tanks during the cool months of the year in Bengal. To obtain Hydra, gather a quantity of water-plants, if possible of the kind called duckweed, or Lemna, and place them in a large glass jar of water. If the jar be

left undisturbed for half an hour or more, the Hydras will become fully expanded, in which state they are easily seen; many of them will have left the weed and may be found attached to the sides of the jar. They can easily be detached and removed by means of a pipette. They will leave the weeds more readily if by artificial means the weeds are shaded, while the lower part of the vessel is in the sunlight. Hydras move towards light. The expanded animal is about half an inch in length, but is not very easily seen by the unaccustomed eye. The body appears as a thin brownish thread, one end of which is fixed to some object, while the other or free end gives out four or five very delicate filaments which are more than twice as long as the body. These filaments are the tentacles; when a minute animal touches one of them it appears to become suddenly attached to it, and the tentacle becomes shortened so that the captive animal passes towards the mouth and is eventually swallowed. A Hydra may be seen to glide slowly down the sides of a glass vessel, sliding upon its base of attachment; sometimes it moves in a looping manner, first one end of the body and then the other becomes attached to adjacent points of the surface along which the animal is moving—in this way the animal takes steps. Sometimes a Hydra may be seen lying free in the water in the fully expanded condition. It may hang nearly motionless in the water or sink very slowly.

Microscopical Examination.—By means of a pipette, place a living Hydra upon a slide in a drop of water,

Place a cover slip over it. The cover slip must be supported by a second one, which is placed under the edge of the first, otherwise the animal will be crushed. The outward form and movements should be studied under the low power. The body of a Hydra is a hollow cylinder which is closed at one end and open at the other. The opening is the mouth. The cavity within the cylinder is the gut, or enteron. Food enters the gut through the mouth. The mouth is surrounded by four or five tentacles, which are capable of great extension. The tentacles, in the extended condition, are slender threads which are covered with nodular swellings. The mouth is at the summit of a short cone, which is separated from the rest of the body by the circle of tentacles. This cone is called the hypostome. Even with the low power it can be seen that the body wall is composed of two layers. The outer layer is transparent and colourless, the inner layer is more opaque and of a brown colour. Examine both the body and a tentacle of the animal under the high power. In both cases look carefully at the surface, and at the margin of the object.

Surface View of the Body.—Examine first the outer surface of the body, and then by focussing downwards examine the deeper layer; it is not very easy to see the individual cells of the ectoderm in the living state. The student will see that the surface is divided by a number of lines, which are disposed somewhat like a net with stretched meshes, but these lines can only be

seen when the animal is contracted, they merely represent the lines of contact of the folds into which the ectoderm is thrown during contraction. The true outlines of the ectoderm cells are visible in the living condition, but I do not think the student will be able to recognize them clearly until after he has examined the cells in the stained condition, and knows the appearance of their nuclei. Small oval bodies known as nematocysts can be seen in the body wall, but they are more numerous and more definitely placed in the tentacles.

On focussing downwards beneath the surface, the endoderm cells come into view. They are said to vary in appearance; but in Calcutta, so far as I have seen, their appearance is constant and characteristic; each cell is of a polygonal shape in this view. They are remarkably like vegetable cells in many ways; they contain so large a vacuole that their protoplasm is reduced to a thin surrounding layer, in which are embedded a number of brown spherical corpuscles and a large nucleus. The endoderm cells are better seen at this stage than any other; the outline of the protoplasm, the vacuole, and nucleus, as well as the brown corpuscles which they contain, can be seen without difficulty. Hydra is sometimes green, in which case the colour is due to the corpuscles of the endoderm cells, which contain chlorophyl; whether they are green or brown these corpuscles are believed to be Algae, which are living in symbiosis with the Hydra. Each endoderm cell is

provided with one or more flagella, which project into the enteron, but are by no means easy to see. It is said that the flagella are not permanent features of the cell structure, but may be withdrawn.

The Body Wall in Optical Section.—Examine the margin of the body, focussing until the line of separation between the ectoderm and endoderm is clearly visible. The two layers are not in contact with one another, but are separated by a very thin layer of gelatinous material called mesogloea. The appearance of the ectoderm in optical section varies according to the degree of contraction in which the animal is found at the moment. When the body is extended the ectoderm is smooth and thin; the depth or thickness of it is about equal to the length of a large nematocyst, but in a state of contraction the ectoderm is two or three times as thick as this, and has a lobulated appearance. The outlines between the ectoderm cells cannot be seen satisfactorily in an optical section of the wall. Whatever the degree of contraction of the ectoderm, the mesogloea always presents the appearance of a straight line. Unlike the ectoderm, it is never thrown into folds; the reason of this will be shown later on. In an optical section of the body wall, the cells of the endoderm appear to be nearly square, otherwise they have the same appearance as in the surface view.

Examination of a Tentacle.—Examine a tentacle in the same way as the body wall. In the first place notice that the tentacle is a hollow cylinder, and that

at the place where it is attached to the body its cavity is in communication with the gut, or enteron. The structure of a tentacle is much like that of the body wall. The ectoderm and endoderm vary in appearance according to the degree of contraction or extension of the tentacle, but the mesogloea which separates these layers has always the appearance of a straight line. There are many nematocysts in the ectoderm of the tentacles. When the tentacle is fully extended, it presents the appearance of a delicate tube with prominent nodular swellings placed upon it at short intervals. These swellings are of the ectoderm, and contain large and small nematocysts. Each swelling usually contains one large nematocyst, around which are placed four or five small ones. The nematocysts are the weapons by which the Hydra captures minute swimming animals for food, and also serve as a protection from the attacks of small fish and other hungry creatures. Nematocysts are of two kinds, large and small; each kind may be seen in two conditions, which may be called the loaded and exploded condition. The surface of a tentacular swelling is studded with thorn-like outgrowths called cnidocils; which, although delicate and transparent, are easy to see. Embedded within the ectoderm at the base of each cnidocil is a nematocyst. The cnidocil acts like the trigger of a gun: when any small swimming animal touches it the underlying nematocyst is caused to explode, that is to say, a minute thread-like tube is shot out from it and enters the soft tissues of the intruder.

A few exploded nematocysts may be seen adhering to the tentacles; they are shaped somewhat like a chemist's flask with the neck drawn out to a conical point. The neck is provided with three or four spines or barbs, which are somewhat curved and very acutely pointed; the conical neck is prolonged into the long thread, which is believed to be tubular. Before explosion the thread and barbs lie within the cavity of the nematocysts; in this condition the neck and barbs are plainly visible. The smaller nematocysts, which are for the most part grouped round the larger ones, are not provided with barbs; the threads, which they rarely eject, are much shorter and stouter than those of the large nematocysts.

Examination of Individual Cells.—Place a living Hydra in a drop of water in a capsule, pour four or five drops of acetic methyl green solution upon it and leave it for three minutes; withdraw the stain with a pipette and fill up the capsule with one per cent. acetic solution. After a minute transfer the Hydra to a drop of clean acetic solution upon a slide. Break it into a few pieces with needles, cover it with a slip, and examine it under the high power. Observe any cells which have become separated from the large fragments, and examine the fragments themselves, paying particular attention to the broken edges. The endoderm cells and the nematocysts have already been fully examined. Observation must be particularly directed to the ectoderm cells.

Epithelio-muscular Cells.—These cells are the principal components of the ectoderm. Along with the other cells

of the body they are killed and fixed by the weak acid present in the stain; but as every part of the body is not usually contracted to the same degree, the forms of these cells are often various. The epithelio-muscular cells can always be recognized by the appearance of their nuclei, which are large and round, somewhat smaller than the large nematocysts, but larger than the small nematocysts, and provided with one or two very distinct nucleoli. If these cells are fixed in the expanded condition, they are flat and irregularly oval or oblong, and much larger than their nuclei—about three times as broad and four times as long; their protoplasm, which is very faintly stained, appears to contain large vacuoles. When these cells are in the contracted state their nuclei are not altered, but the cell body is roughly cubical and in all its dimensions is only equal to about twice the diameter of the nucleus. The most remarkable part of the epithelio-muscular cells are the muscular processes which are attached to their inner sides, and are in contact with the mesogloea. Each cell is usually provided with two such fibres, which project in opposite directions. The processes of adjacent cells lie parallel with one another and with the longitudinal axis of the animal; they give the body a striped appearance which is plainly visible in the stained specimen. By searching among the broken portions of the ectoderm, the muscular processes may be seen attached to the cells of which they are a part.

Interstitial Cells.—The epithelio muscular cells are

the principal components of the ectoderm; their adjacent edges are in contact with one another at the surface, but below the surface those cells are separated from one another by other cells, called interstitial. Interstitial cells therefore lie beneath the epithelio muscular cells, and are placed so as to separate the deeper parts of these cells from one another. Interstitial cells become stained more deeply, and possess smaller nuclei, than the larger epithelio muscular cells. The nematocysts are secreted by interstitial cells and can be seen within them.

Reproduction.—There are two methods of reproduction—sexual and asexual. When water is plentiful, and the circumstances of life are favourable, the Hydra forms buds. These are simple outgrowths from the lower part of the body, which soon come to resemble the parent Hydra in every way. They become detached and lead an independent life. During the cold-weather months most large Hydras show one or more such buds, but at the approach of the hot weather, when the conditions of life begin to be unfavourable, germ-cells, or gametes, which are formed from interstitial cells of the ectoderm, make their appearance. The male gametes, or spermatozoa, are agglomerated together so as to form small conical swellings, which project from the body wall below the bases of the tentacles. Each spermatozoon consists of a minute oval head, which is mainly nucleus, and a long flagellum, or tail, by means of which the head can be propelled through the water. Among the Metazoa, those organs in which spermatozoa are formed are called

testes. The female gamete, or ovum, is usually single, and is produced by the same individual that produces spermatozoa. Animals in which both male and female gametes are produced by the same individual are called hermaphrodite. The ovum of a Hydra is an enlarged interstitial cell, which becomes surrounded and nourished by a number of other interstitial cells; it becomes amoeboid, and grows rapidly at the expense of the surrounding cells, and stores up reserve food material or yolk within its substance. The ova of many other Metazoa are developed in this way at the expense of smaller cells which surround them, and are together called the follicle of the ovum. When the ovum is mature, a spermatazoon, probably from another individual, swims through the water towards it and unites with it, so that the nuclei of both ovum and spermatozoon become fused together. This is the act of fertilization; the resulting cell is a zygote or fertilized ovum, which, by segmentation, develops into another Hydra. Development is slow, and probably proceeds throughout the hot-weather months. The developing ovum is protected by a chitinous shell, which is formed soon after the act of fertilization.

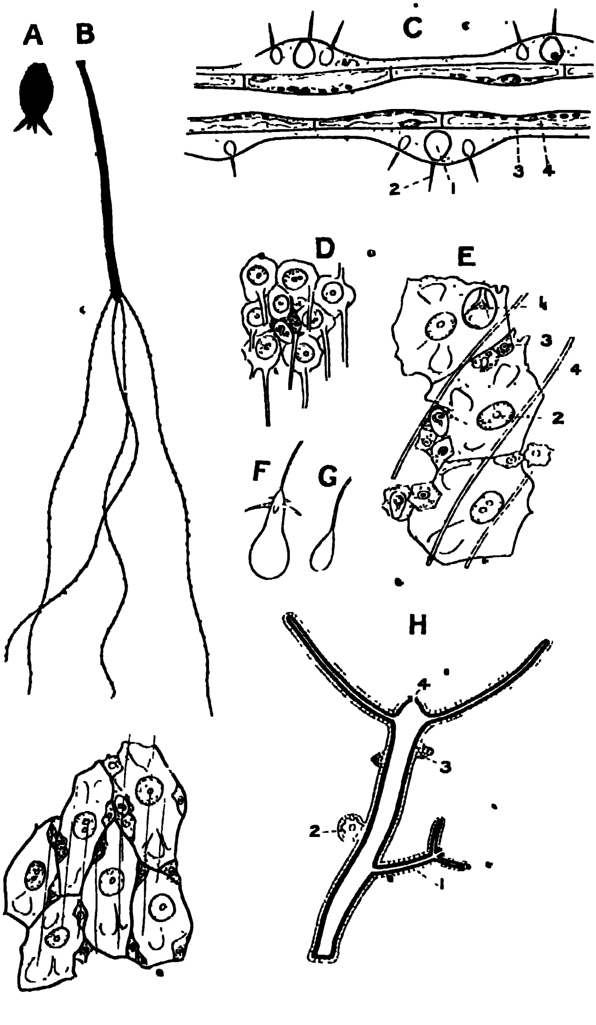
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PLATE IV.

HYDRA.

A. Hydra contracted.

B. Hydra fully extended.

C. Optical section of a tentacle. 1. large nematocyst; 2. cnidocil; 3. mesoglea; 4. endoderm cells.

D. A group of musculo-epithelial cells in a state of contraction.

E. Three musculo-epithelial cells fully expanded. 1. nematocyst; 2. nucleus of M. E. cell; 3. interstitial cells; 4. contractile thread of a M. E. cell.

F. Large nematocyst.

G. Small nematocyst.

H. Diagram of Hydra. 1. a bud; 2. ovum; 3. testes; 4. mouth.

J. Surface view of living ectoderm. (The cell outlines are too thick.)

A. and B. × 20. C., D., E., 450 (approx.). As figures D. and E. appear somewhat unlike the illustrations in other books, it must be said that they were drawn, with the help of the camera lucida, from portions of a hydra which had been treated in the manner described in the text.

CHAPTER III

TRIPLOBLASTICA—ANNELIDA

COELENTERATE animals are said to be diploblastic because their component cells are arranged in two layers, ectoderm and endoderm, which are not separated from one another by any important tissue. The higher animals are said to be triploblastic (three layered), because the endoderm and the ectoderm are separated from one another by several important tissues which are spoken of collectively as the mesoderm. Worm-like animals are among the simplest of the Triploblastica.

The Annelids are segmented coelomate worms. The word "segmented" expresses the fact that the soft, elongated body is marked externally by a series of encircling grooves, which divide it into a number of conjoined pieces called the segments. The external segmentation corresponds to an internal segmentation, for some of the most important systems of the body are divided into a series of like parts, which are distributed individually through the segments. Thus, for example, each segment contains a piece of the intestine, of the nervous system, of the excretory system, and of the vascular system; therefore the segments are, for the most

part, exactly like one another, internally as well as externally. A coelomate animal is one which possesses a coelom. In the body of many animals there is a cavity which is lined by a layer of flat cells; this cavity is the coelom, and its lining is the coelomic epithelium. The coelom of an animal often surrounds some part of the alimentary canal, separating it from the body wall. The coelom is filled with a fluid containing amoeboid corpuscles; it communicates with the outer world through tubes called nephridia, which have an excretory function. The germ cells of a coelomate animal always arise by budding from a spot on the coelomic epithelium, and find their way out of the body through ducts which, like the nephridia, lead from the coelom to the outer world. In most of the Annelids the coelom is segmented, that is to say, it is divided into a series of separate compartments, one of which is placed in each segment. The gut, or alimentary canal, of an Annelid is a straight tube which opens at both ends of the body; the apertures of the gut are the mouth and the anus.

Before proceeding further we must define certain terms. The surface of the body which is nearest the ground when the animal is crawling is called ventral. The surface which is uppermost is called dorsal. It is not easy to define the terms dorsal and ventral so that the definitions will apply to all kinds of animals. In man, because of his upright posture, the ventral surface is to the front, not towards the ground. The dorsal surface of an animal has been defined in the following

manner: many imaginary lines may be drawn outside the body from mouth to anus, but only one of them will lie directly over the brain; this one will indicate the dorsal surface. The terms anterior, posterior, and lateral are much used in comparative anatomy. The anterior end of an animal is that at which the mouth opens; the posterior end is where the anus is to be found. But difficulties sometimes arise in using these terms; for example, in a gasteropod mollusc, the mouth and anus open in the same direction. Things which lie on one or other side are lateral. An essential feature in the structure of many animals is their bilateral symmetry; that is to say, they can be divided by a median plane into two equal parts, which are exactly similar to one another. The occurrence of organs in pairs, which are placed one on either side of a median plane at an equal distance from it, is very common in the animal kingdom. All Annelids are bilaterally symmetrical.

The central nervous system is of a type which is also found in the great group of the Arthropods. There is a long white chord placed in the median plane, close to the ventral body wall, between it and the alimentary canal; it is not of uniform thickness, but is enlarged or swollen at a certain spot in each segment of the body. The swellings are called ganglia. The chord is composed of many delicate threads or nerve fibres. In a ganglion the fibres are interspersed with nerve cells, irregular nucleated pieces of protoplasm from which the nerve fibres arise as outgrowths. Every nerve fibre arises

from, and is connected with, a nerve cell. Nerve fibres are of two kinds—sensory and motor. Sensory nerve fibres are outgrowths from sensory cells, which are elongated, spindle-shaped bodies situated among the cells of the skin. One end of a sensory cell projects out of the skin as a delicate filament, which is comparable to a cnidocil of a Hydra, the other end is prolonged into the body as a sensory nerve fibre. Sensory fibres are united to form strands, which are called sensory nerves, and make up some of the number of nerves which we see in connection with the ganglia. All nerve fibres have the function of transmitting a kind of activity which is called a stimulus or impulse. A stimulus originates in sensory cells of the skin, and moves along sensory nerves towards the central nervous system, from which it passes along motor nerves towards the muscles and causes them to contract. The motor fibres arise from the nerve cells in the ganglia, and pass out of the central nervous system in the motor nerves which end among the muscles. The special peculiarity of the nervous system of the Annelids and Arthropods is the ventral position of the gangliomated nerve chord. Although the chord may appear to the naked eye to be single, it is really composed of two strands lying side by side which are in contact with one another. Similarly, the ganglia are double; there is a pair of them lying side by side in each segment. The most anterior pair of ganglia lie beneath the oesophagus, close to the mouth, and are called the suboesophageal ganglia; two thick

strands of fibres issue from them, one on either side, and pass round the oesophagus, to meet above it. These strands are called the circumoesophageal connectives; they meet above the oesophagus in a pair of ganglia which are called supraoesophageal or cerebral. Every ganglion sends out nerves to the skin and muscles of the segment in which it lies.

The Annelids possess a well-developed circulatory system. Many animals are provided with a system of tubes filled with blood, which moves through them and carries oxygen and nutrient materials to every living particle of the body. The blood also removes the waste products of metabolism, such as carbon dioxide and urea. In order to subserve these functions, the blood-vessels must be intimately connected with every part of the body, and in particular with the surface of the alimentary canal, from which the nutrient material is derived, with the surface of the respiratory organs, through which oxygen is taken in and carbon dioxide given out, and with the excretory surface, from which the waste products are thrown out of the body. Furthermore, the blood must be made to move or circulate in the tubes. If a tube which is full of fluid be squeezed at a certain spot, the contained fluid will move from that spot. If the inner wall of the tube is furnished with valves which, like the doors of a house, open in one direction only, the fluid must move in that one direction. The walls of the blood-vessels of an animal contain muscle fibres, which encircle them and

have the power of contracting; when they contract they become shorter, so that the calibre of the vessels becomes diminished, and the contained blood is made to move. It can only move in one direction because of valves, which resemble pockets and are attached to the inner walls of the vessels. A certain part, or parts, of the vascular system have the power of rhythmic contraction, that is, to say, of alternate contraction and relaxation; these special parts are called the heart or hearts. In the Annelids the hearts are several and tubular, in the higher animals the heart is a more complex organ, but it is always developed in the embryo from a tube. In the lower animals the blood-vessels are of one kind, but in vertebrate animals they are of two kinds, called arteries and veins.

In the skin of all Annelids are embedded certain chitinous rods called setae. Chitin is a lifeless, horny, and transparent material, which is often secreted by invertebrate animals, either as a protective covering to the whole body, or at certain spots where a hard substance is required to withstand friction. The Annelids are divided into two principal groups, the Oligochaetes, which have few or inconspicuous setae, and the Polychaetes, which have many. Polychaetes occur only in the sea. The Oligochaetes are found on land or in fresh water; they include the great sub-group of Terricola, or earth-worms.

THE EARTH-WORM (*Pheretima posthuma*)

There are so many different kinds of earth-worms in India that it is difficult to choose one as a type for dissection. In the neighbourhood of Calcutta as many as five different genera may be found by digging in one spot, all of which are different from one another in structure. Perhaps the commonest and most easily recognized is one which was called Perichaeta indica, a name which has been changed to Pheretima posthuma. Worms of this kind can be recognized by their outward appearance. In all earth-worms the skin of the body has a pale, swollen appearance at a spot situated an inch or more from the anterior end. This area of swollen skin, which encircles the body, is called the clitellum. In Pheretima posthuma three pairs of conspicuous apertures open upon the ventral surface close behind the clitellum, and there are always thirteen segments in front of the clitellum. Worms which possess these outward features resemble one another closely, but not exactly, in their internal anatomy; nor do they exactly resemble one another in outward appearance: for example, some are about four inches in length and of an olive-brown colour, others are half as large again and of a pinker colour. As a rule, worms of this species which are found in one place resemble one another very closely, although frequently two or three distinct genera may be found in the same spadeful of earth.

External Appearance.—By the position of the clitellum

and of the generative apertures, the student can recognize both the anterior end and the ventral surface of the worm. The mouth is a large aperture at the anterior end, which is surrounded by the first segment as by a ring. Overhanging the aperture is an insignificant fleshy lobe called the prostomium. There are thirteen segments in front of the clitellum, which includes three segments in itself. Posterior to the clitellum are the 17th, 18th, and 19th segments, each of which is provided with a pair of conspicuous apertures; those on the 18th segment are the apertures of the male generative ducts; they are a little larger than the other four, which are the openings of the accessory glands. The segments need not be counted beyond the 19th; there are about a hundred of them in all. Each segment of the body is armed with a large number of chitinous setae. These are like pegs embedded in the skin and placed in rows, one of which completely encircles each segment of the body. Sometimes the setae are so large as to be easily visible and palpable; at other times a row of minute depressions in the skin, visible only with the help of a strong lens, is the sole indication of their presence. In the middle dorsal line between each segment there is a minute pore, through which each compartment of the coelom communicates with the outer world. When the animal is in water a stream of brownish coelomic fluid can often be seen to issue from these pores. When a live worm is dropped into spirit, coelomic fluid is poured forth from them in quantities.

There is a kind of earth-worm which squirts fluid from its dorsal pores to a distance greater than twelve inches if it be handled. This action is obviously defensive. The other apertures of the body are best examined after the various organs have been seen from the inside.

Dissection.—Pin the worm down on its ventral surface in a flat dish, and cover it with water; the pins should be inserted through the first and last segments and the body stretched straight between them. Cut the skin with fine scissors in the mid-dorsal line along the whole length of the worm; the cut must not be deep, otherwise the underlying intestine will be injured. The incision will divide the whole body wall, including the skin, two layers of muscle fibres, and the outer or somatic layer of the coelomic epithelium. The cut edges must be grasped with forceps, stretched asunder, and pinned down, so that the entire body wall comes to lie flat upon the dissecting dish. The alimentary canal, which lies in a straight line between the two extremities of the animal, is thus exposed. The coelom, or space between the gut and the body wall, now lies freely open.

The Coelom and Septa.—The coelomic space is divided into a number of compartments by as many membranous partitions called septa, which are fixed to the inner side of the body wall opposite the grooves separating the segments from one another. The septa should be examined, beginning with the most anterior. The first definite septum lies between the 4th and 5th segment, hence the coelom of the first four segments is a single

cavity. The first septum is thin and membranous. The next three, which separate segments V, VI, VII, and VIII from one another, are thick and opaque. The septum behind segment VIII is also somewhat thickened, but all the others throughout the body are thin and translucent. In worms of the kind we are dealing with, one out of those septa which are anterior to the clitellum is usually missing. In some there is no septum between segments VIII and IX, in others there is a septum in this position, but there is none between segments IX and X. The other septa are always present so far as I have seen, and sometimes there is no missing septum.

Some of the coelomic fluid from a fresh worm should be examined under the microscope; it may be obtained either from the dorsal pores by squeezing, or from a cut made in the body wall. It should be mixed with salt solution, and examined under the high power. The coelomic fluid contains three kinds of cells: those of one kind are full of yellowish granules, which render them opaque and conspicuous; others are spherical, transparent, and devoid of granules, but provided with a small central nucleus; they closely resemble the cells which are found in the blood. The third kind are the Phagocytes. These are smaller than the others; they are nucleated and irregular in shape, and exhibit amoeboid movement. The Phagocytes often contain ingested bacteria, which abound in the coelomic fluid.

Alimentary Canal.—The mouth leads into a pharynx, which lies within the first four segments. The dorsal

wall of the pharynx is thick and muscular, and is attached to the body wall and to the first septum by strands and sheets of tissue resembling incomplete septa. The opening of the oesophagus into the pharynx is overhung by a soft fleshy shelf, which is placed horizontally. When alive Pheretima has the habit of protruding and retracting its pharynx; this is most noticeable when the worm is placed on a wet surface. The pharynx may be protruded a quarter of an inch beyond the prostomium, which is a fixed point. This action may be performed in order to swallow water, or it may be a means of progression. The oesophagus is a narrow tube which leaves the pharynx in the 4th segment and passes through the 5th, 6th, and 7th segments. It usually perforates the 1st septum at a point above its centre, and descends as it passes through the three segments; while in the 5th segment it receives on either side the openings of the ducts of the oesophageal glands. These are a pair of conspicuous organs which look like a bunch of red grapes, when magnified. The oesophagus opens into the crop, a round organ with thick muscular walls, which in some worms is placed in the 8th segment; in others it occupies both the 8th and 9th segments, owing to the absence of the septum, which should intervene between these two segments. The intestine lies in a straight line between the crop and the anus; after passing through the 13th segment it becomes wider. In the 26th segment it gives off on either side a tubular pouch, which ends blindly near the posterior end of the prostate gland of the same

side. These pouches are called the intestinal coeca. The surface of the intestine is covered with a yellow powdery substance which is easily rubbed off. If some of this substance be examined under the microscope, it will be seen to consist of cells which are full of yellow granules. Cells of this kind have already been seen in the coelomic fluid. The yellow granules are nitrogenous waste material, which has been extracted from the blood as it passes through the lateral intestinal vessels. A small piece of the hinder part of the intestine should be cut out and examined after its contents have been washed away. In the mid-dorsal line the wall of the intestine is folded in so as to form a projecting ridge, which is called the typhlosole.

Vascular System.—The vessels are filled with red blood. The red colouring matter resides in the fluid or plasma of the blood, not in the corpuscles. When examining the blood microscopically, care must be taken that it is not contaminated with the coelomic fluid. Pure blood can be obtained from an excised heart; it contains a few round nucleated cells, or corpuscles, which do not appear to be amoeboid. Along the upper surface of the gut, in its whole length, lies the dorsal vessel; similarly, beneath the gut is the ventral vessel. The dorsal vessel gives out in each segment two lateral intestinal vessels, which pass round the gut to join the ventral vessel. In the 12th and 13th segments, the lateral vessels which encircle the gut are single on either side and very conspicuous; these enlarged vessels have the power of

rhythmic contraction, and are called hearts. There is a small vessel beneath the dorsal vessel which may be called subdorsal. In segments XII and XIII it communicates on either side with the hearts; which therefore have three communications, namely, with the dorsal and subdorsal vessels above the intestine, and with the ventral vessel below it. There is a vessel which lies horizontally alongside that part of the intestine which is anterior to the coeca; there is also a small one beneath the nerve-chord, which is called the subneural vessel. The ventral vessel supplies branches to the nephridia in each segment. The body wall is supplied from the dorsal and subneural vessels by small branches, which are called the parietal vessels.

The blood glands are a series of small white organs, which lie upon the intestine on either side of and close to the dorsal blood-vessel. There are a pair of blood glands in each segment of the body, posterior to that in which the intestinal coeca are situated. The function of these glands is unknown; they consist of a mass of nucleated cells, which may be blood cells, or phagocytes in a state of development. Tissue in which new amoeboid cells are developed is described as lymphoid.

There are no special respiratory organs in the earthworm; the skin is plentifully supplied with minute blood-vessels or capillaries. Oxygen passes through the skin and enters the blood, which is circulating in the capillaries. Similarly, by a reverse route, carbon dioxide is given off from the blood to the outer air.

Generative Organs.—All earth-worms are hermaphrodite, that is to say, the male and female germ-cells are produced in one and the same individual. The female germ-cells, or ova, are formed in a pair of small bodies called the ovaries; the male germ-cells, or spermatozoa, are formed in two pairs of smaller organs called the testes. Both ovaries and testes are developed in the same manner. At a certain spot on the coelomic wall, the epithelial cells undergo rapid growth and division, so that small masses of cells, which are the germ-cells, project from the smooth surface of the epithelium into the cavity of the coelom. The germ-cells become detached from the ovaries and testes, and fall into the coelom; they leave the body by passing through tubes, which open at one end into the coelom and at the other upon the surface of the body. The coelomic openings of the tubes are widely funnel-shaped. The tubes which give passage to the ova are called the oviducts, those which convey the spermatozoa are called vasa deferentia. The oviducts open into the common coelomic cavity, but the vasa deferentia open into a special closed part of the coelom called the seminal vesicle.

In order to see the generative organs the gut must be removed; it should be cut through at the coeca and raised from behind. The septa which hold the gut down should be cut as close to the intestine as possible.

Female Generative Organs.—The ovaries are found in the 13th segment, *i.e.* the segment next in front of the clitellum. They are attached to the septum which forms

the anterior wall of that segment, and lie close on either side of the nerve-chord. They should be removed and examined under the microscope. The base of an ovary is continuous with the septum, and is compact and granular; the other or free end of the organ consists of a number of separate filaments, each of which contains a row of mature eggs resembling a string of beads. The oviducts are two short tubes, which perforate the septum between the 13th and 14th segments; the internal or coelomic opening of each is surrounded by a wide funnel with folded margins, which lies in the 13th segment. After perforating the septum, the oviducts converge and meet one another beneath the nerve-chord. The external opening is single, and lies in the mid-ventral line upon the clitellum, immediately in front of the row of setae which belongs to the 14th segment.

Male Generative Organs.—These consist of the testes, seminal vesicles, vasa deferentia, and prostates. The seminal vesicles are the conspicuous organs which are seen in segments X, XI, and XII; they consist of two median vesicles which lie beneath the gut, and three pairs of lateral vesicles which lie on either side of the gut and partially embrace it. The median vesicles are in segments X and XI, the posterior one being the larger; the lateral vesicles lie in segments X, XI, and XII. Within each median vesicle is a pair of testes and a pair of seminal funnels, which resemble the funnels of the oviducts in size and appearance. As the ova drop from the ovaries, so do certain cells called spermatoblasts

drop from the testes. The development of the spermatozoa takes place within the seminal vesicles. A piece of one of the lateral vesicles should be cut off, and its contents squeezed into a drop of salt solution upon a slide and examined under the microscope. The spermatozoa are developed out of the spermatoblasts, which are simple round cells containing one nucleus. A mature spermatozoon consists of an elongated head, which is the nucleus, and a long fine protoplasmic filament or tail. Each spermatoblast gives rise to fifty or more spermatozoa. Part of the spermatoblast remains over as a residue of protoplasm, which takes no part in the formation of the spermatozoa. Each seminal funnel is the mouth of a fine duct or vas deferens; the two ducts of a side come in contact in the 12th segment, but do not unite; they pass in close company through several segments and finally open into the prostatic duct in the 18th segment.

The prostates are a pair of large glands of an irregular nodular shape and of a whitish colour, which lie on either side of the intestine posterior to the region of the clitellum. They belong to the 18th segment, but project beyond it into the neighbouring segments. Each prostate gland has a short, wide duct, which opens by the male generative aperture upon the 18th segment; the double vas deferens joins the prostatic duct as it issues from the gland. The function of these glands is not certainly known. In some kinds of earth-worms they are absent, in others they are tubular, or of other

shapes; this is remarkable, because it seems that the mode of life and the generative functions of all the various kinds of earth-worms must be nearly alike. The term prostate is used to describe a gland which secretes a mucoid fluid as a carrying medium or vehicle for spermatozoa. There are a pair of glandular pouches in segments XVII and XIX; these are the accessory glands, their function is unknown. They open conspicuously in series with the male generative aperture.

The Spermathecae.—The spermathecae are receptacles for mature spermatozoa which have been received from another worm. They are eight in number, and lie in pairs on either side of the gut from the 6th to the 9th segment. Each spermatheca consists of an ovoid pouch and a narrow coecum, which protrudes from the neck of the pouch. The neck of each is a narrow tube which opens upon the skin in the groove between two segments. The disposition of the spermathecae is particularly subject to variation. A spermatheca should be removed and its contents examined in salt solution under the microscope. The mature spermatozoon consists of an elongated head, which is prolonged into a delicate thread-like tail. Unless the light is properly regulated the tails will not be seen; they are often actively motile.

Excretory System.—The excretory system of Annelids consists of a series of tubes distributed through the segments. Each tube has an opening at either end, the one into the cavity of the coelom within the body, the other upon the skin outside the body. In the

European earth-worm Lumbricus there are in each segment a pair of such tubes which are called nephridia; each one opens into the coelom by a minute ciliated funnel; the neck of the funnel passes through one of the septa, so that the main part of the nephridium lies within, and opens upon the skin of, the segment next behind that in which the funnel opens. Much of the tube consists of a series of elongated cylindrical cells placed end to end; in the axis of each cell is a channel, which is said to be intracellular, for it appears as though excavated through the solid protoplasm of the cell. The nephridial tube is therefore like a drain-pipe which is composed of numerous individual lengths of piping. The excretory system of Pheretima is different from that of Lumbricus: in place of the two separate tubes there is a diffuse ramifying system of tubules, with many funnel-like openings in each segment, and many minute external apertures which are scattered irregularly over the skin.

A short length of the intestine should be removed with as little damage to the septa as possible, the remaining body wall should be washed, and the septa examined with a lens. Each septum is for the most part smooth, but near where it unites with the body wall it has a shaggy appearance, which is due to a collection of minute tubules. A piece of septum should be cut off as close as possible to the body wall; it should be floated on to a slide, covered and examined in water under the microscope, or it may first be stained with acetic methyl

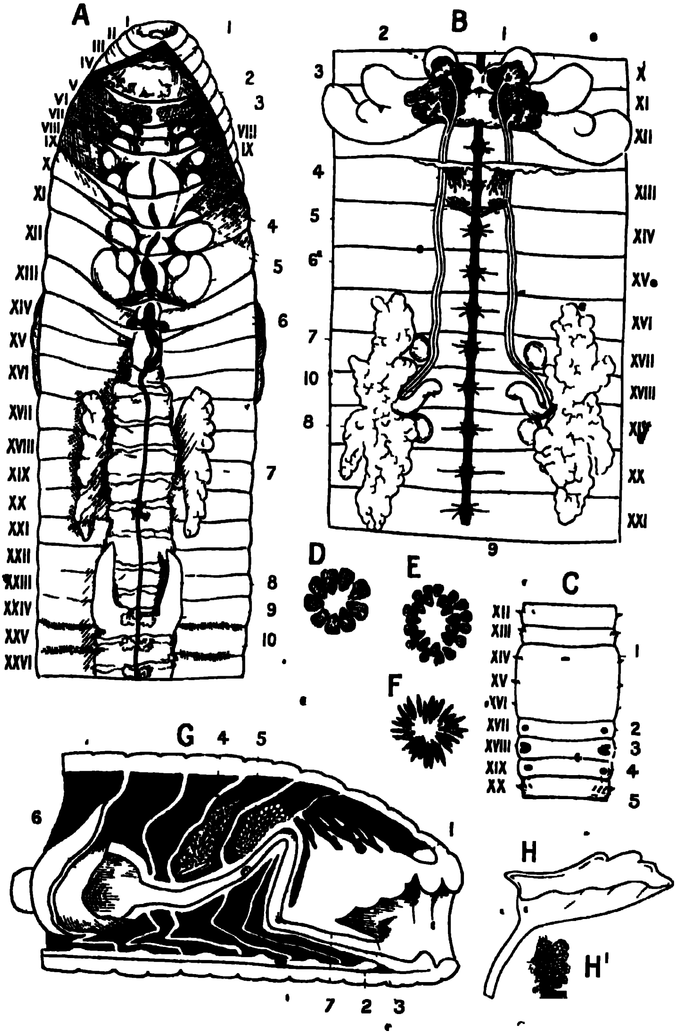

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PLATE V.

THE EARTHWORM (*Pheretima posthuma*).

A. 1. brain; 2. pharyngeal gland; 3. spermatheca; 4. crop; 5. seminal vesicles; 6. hearts; 7. prostate gland; 8. coecum; 9. blood gland; 10. nephridia.

B. 1. median seminal vesicle; 2. seminal funnel; 3. lateral seminal vesicles; 4. ovary; 5. oviduct; 6. vas deferentia; 7. accessory gland; 8. prostate; 9. nerve-chord; 10. prostatic duct. (The alimentary canal has been removed.)

C. The ventral surface of the body in the region of the clitellum; 1. opening of oviduct; 2, 4. openings of accessory glands; 3. male aperture; 5. setae. (The setae are too conspicuous, especially on the clittelar segments.)

D, E, F. Three stages in development of spermatozoa taken from a seminal vesicle, drawn from stained specimens; the coarse granules are chromatin. The tails of the spermatozoa are not shown; they are best seen in mature and living spermatozoa.

G. Median longitudinal section of the first eight segments. 1. Brain; 2. Suboesophageal ganglion; 3. Pharyngeal shelf; 4. Nephridia copiously developed in the 6th segment; 5. Pharyngeal glands; 6. crop; 7. fleshy roof of pharynx.

H. Seminal funnel.

H'. Testis.

(D–F × 450; H. and H'. × 25.)

green. A large number of contorted tubules are seen attached to both sides of the septum. The channels within these tubules are intracellular, as in Lumbricus. The septum is pierced by numerous ciliated funnels, which are the coelomic openings of the nephridial tubules. The external openings of the tubules can only be seen in sections of the body wall which have been cut with the microtome. The body wall consists of an outer skin, or ectoderm, and two layers of muscle fibres, one within the other. The outer muscular layer is composed of fibres which encircle the body; the fibres of the inner muscular layer are placed longitudinally and are separated from the coelom by a thin coelomic epithelium. Many tubules of the nephridial system ramify between the coelomic epithelium and the body wall, and find their way irregularly between the fibres of both muscular layers towards the skin, upon which they open by very minute apertures.

CHAPTER IV

PLATYHELMINTHES—NEMATODES

Any elongated animal which is soft and flexible may be described as worm like. The Platyhelminthes are worm-like animals in which the body is flattened. They occur in various circumstances; in the sea, in fresh water, among moist vegetation, or as parasites upon or within other animals. Although the various kinds of flat worms are very different from one another in certain features of their anatomy, they all agree in the following points: they are elongated and flat. In some there is a gut, in others there is none. When present the gut is provided with one opening the mouth; there is no anal aperture. There is no coelom, or body cavity; the interval between the gut and the body wall is occupied by soft mesoderm, which is composed of an irregular network of branching nucleated cells. In the Cestodes, which are devoid of a gut, the whole interval enclosed by the body walls is occupied by mesoderm. The excretory system is of a certain type which is peculiar to the group; it consists of a tree-like system of branching tubules; those parts of the system which represent the ultimate twigs of the

tree are fine tubules scattered throughout the mesoderm, and terminating in remarkable structures called flame cells, but that which represents the trunk of the tree is a larger tube, which opens upon the outer surface of the animal and discharges the waste products. Flat worms are nearly all hermaphrodite.

The Platyhelminthes are divided into three sub-groups—the Turbellaria, Trematoda, and the Cestoda. The Turbellaria, for the most part, lead a free life, either in the sea or in fresh water; they are covered with cilia and possess a gut, which usually opens in the middle of the body by a single aperture. The other two groups are parasites upon, or more usually within, the bodies of higher animals. Trematodes are provided with a gut, which opens near one end of the animal by a small aperture; they are also furnished with disc-like suckers, by means of which they cling to the host. A well-known example of a Trematode is Distomum, the liver fluke, which is parasitic in sheep. A liver fluke is an oval flat body, about one inch long and half as broad, which sometimes occurs in great numbers in the liver and bile ducts of sheep; it feeds upon the liver substance and may cause the death of the sheep. This parasite is not common in India, though some kinds of Distoma are found from time to time in the body of man. The life-history of Distomum is of remarkable interest. The mature animals give forth a very large number of minute eggs, which are protected by resistant shells. These

eggs pass down the bile ducts of the sheep and enter the intestine; they leave the intestine, together with the faeces; if they fall upon wet grass, they each give rise to a minute ciliated embryo, which seeks out a certain small snail which may be living among the wet grass; they bore their way into the body of the snail, and there undergo further development. Although they are in a larval condition, they reproduce their kind within the body of the snail, so that although perhaps only one larva enters a particular snail, a large number issue from it when the snail is weakened by the attack. The larvae which finally leave the snail are in a more advanced stage of development than those which entered it; although very small, they possess most of the essential features of the mature fluke; they surround themselves with a cyst wall and rest among the grass; when by chance they are swallowed by a grazing sheep they find their way into the liver by passing up the bile duct; here they become mature and lay their eggs, so that the complicated cycle is repeated.

The Platyhelminthes exhibit various degrees of parasitism. Most of the Turbellaria are free-living worms, but there are a few which live in association with other animals. All the Trematodes are parasites; some of them, however, live upon the outside of their host. Trematodes of this kind may be found upon the skin or clinging to the gills of fish; they have several large suckers, which enable them to cling to their host;

they do not produce a very large number of eggs. Trematodes such as Distomum, which are internal parasites, have only two small suckers and produce a very large number of eggs. Their life cycle is complicated, and depends for its success upon many circumstances; it is therefore necessary that a very large number of eggs should be produced in order that at least a few of them may pass through the complete cycle. Parasites belonging to the same family as Distomum are very common in the intestines of frogs.

The Cestodes, or tape-worms, illustrate the most advanced degree of parasitism, and as they are often met with, both in the mature condition and in a state of development, they will be described in more detail.

Taenia saginata.—This tape-worm is a common parasite of man in India and other countries; it may be obtained after it has been evacuated by medical treatment. Much of the structure of a tape-worm can be seen in permanently preserved specimens. Small living tape-worms of other species may often be found in the intestines of common rats, also in cats, dogs, fish, and even pigeons. There are two separate forms or stages in the life-history of Taenia saginata, both of which are parasitic, but each in a different species of animal. One form which may be spoken of as the tape-worm is sexual and produces eggs; it is a long, flat worm which lives within the intestine of man. The other form, which is called the cystic larva, is a

round bladder-like body, somewhat larger than a pea, which is found embedded in the muscles of an ox.

The Tape-worm Stage.—A mature specimen of Taenia saginata may measure as much as ten feet in length; it is flat and of a white colour. The whole body is divided into a large number of conjoined segments; any two adjacent segments resemble one another, but all are not alike. If the eye passes along the whole length of the worm, it will be seen that a progressive change occurs in the outward shape of the successive segments. If the two ends are examined it will be seen that they are different from one another. One end of the worm is broad and flat, and is composed of segments which are clearly marked off from one another; the other end is slender and cylindrical, and terminates in a small swelling or head, which is buried in the intestinal wall of the host and constitutes the only means of attachment of the parasite to the tissues of the host. The slender part of the body, which is immediately below the head, may be called the neck; it is not segmented, but an inch or so from the head segmentation becomes visible; at first the segments are very small and are broader than they are long, but at a distance of eight or ten inches from the head they are square, measuring about one quarter of an inch in length and breadth; as the segments become further and further removed from the head, so do they increase in size, and their length becomes greater than their breadth. The terminal segments are about

three-quarters of an inch in length, and three-eighths of an inch in breadth. In accordance with the progressive change which occurs in the outward appearance of the segments, there is a similar progressive change in their internal structure, a change which affects the generative organs only. The smallest segments, which are nearest the head and may be called the youngest segments, do not contain generative organs, but as the segments become older and further removed from the head these organs appear in them. All stages in the development of the generative organs can be seen in a complete worm, from the first appearance of the germ-cells to the formation of the fertilized eggs. The terminal segments are filled with a large number of fertilized eggs, each of which is protected by a resistant shell. These segments, which are known as proglottides, become detached from time to time and pass out from the intestine along with the faeces.

Much of the structure of Taenia can be seen in pieces of the body which have been stained and permanently mounted in Canada balsam. The head and a segment from the middle of the body, as well as one of the terminal segments (which have been treated in this way), should be examined.

The Head or Scolex.—The head is about the size of a pin's head, and is shaped like a round cushion; it is furnished with four suckers, which are placed laterally and serve as a means of attachment; immediately below the head the neck shows signs of annulation, but well

defined segments do not appear until further down. The heads of many species of tape-worm are provided with chitinous hooks, which are a means of attachment additional to that afforded by the suckers; these hooks are arranged in a ring around the top of the head, and are therefore spoken of as the crown of hooks.

A Middle Segment.—A segment from the middle of the body shows ripe generative organs, both male and female. The male organs consist of a large number of small spherical testes, which are scattered irregularly throughout the whole segment; they are connected by a system of fine ducts with a vas deferens, which opens at the common generative aperture upon the edge of the segment. The female generative organs consist of five parts—the ovaries, the yolk gland, the shell gland, uterus and vagina, which are arranged as in the diagram. The ova are formed in the ovaries; they become fertilized by spermatozoa, which enter the segment through the vagina. The vas deferens ends in a tubular organ, or penis, which can be protruded through the common generative aperture. The segments may fertilize themselves or each other. The eggs receive nutrient material from the yolk gland, and by the activity of the shell gland become covered with a thick chitinous shell; in this ripe condition they pass into the uterus, which is a tubular pouch lying in the middle of the segment. As the segments become older and further removed from the head, their uteri become filled with eggs to a greater and greater extent, and therefore become more and more

conspicuous, but the other generative organs dwindle and disappear.

Terminal Segment.—The terminal segments therefore contain a complex uterus which is filled with hard-shelled eggs. The main body of the uterus is still median in position, but a great number of side branches have appeared in order to accommodate the large number of eggs.

Alimentary System.—A tape-worm has no alimentary canal. The interval enclosed by the body wall is filled with spongy mesoderm, among which the generative organs lie. The function of an alimentary canal is to digest the food material which it receives, so as to enable the nourishment to pass through the wall of the intestine into the blood stream; in the process of digestion the insoluble proteid food-stuffs are converted into soluble peptones. Now, a tape-worm lies in the intestine of another animal, and is therefore surrounded by peptone and other soluble nutriment which, although belonging to the host, passes through the skin of the parasite and nourishes its body; an alimentary canal is therefore unnecessary to a tape-worm.

Nervous System.—The central nervous system is the centre of the mechanism by which an animal responds to the many events which occur around it. For example, the body of an earth-worm responds to the changing degrees of light, heat, and moisture, to vibrations and many other events; it responds to them in order that its life may be preserved. But the tape-worm, lying

within the intestine of another animal, is little subject to changing events, consequently a well-developed nervous system is unnecessary. There is a ring of nerve-tissue in the neck, and two strands of fibres which pass from it through all the segments of the body; these strands lie close to the margins, one on either side.

The Excretory System.—This consists of two channels, one of which accompanies the nerve-chord on either side; the two are connected in each segment by a transverse channel, and open to the exterior at the end of the last segment. A number of fine tubules spring from the main channels and form a ramifying system among the mesoderm; these tubules, which are very minute, are composed of cylindrical cells containing an intracellular duct, as in the nephridium of an earth-worm. Each terminal twig of the system ends in a hollow ovoid bulb which somewhat resembles a chemist's flask; inside the bulb there is a long flagellum, which is fixed to the wall and moves in an undulating manner. The movement was compared to the flickering of a candle flame, hence these terminal bulbs, which are merely expanded and excavated cells, are called flame cells. Flame cells can only be seen during life, and are never easy to see. The main channels of the excretory system are plainly visible in most species of tape-worms, especially during life.

The Life History.—The terminal proglottides are evacuated with the faeces; at the time of evacuation they are capable of movement, and because of their white colour they are conspicuous objects. The walls

of the proglottides soon become disintegrated; the hard-shelled eggs are liberated, and become scattered with the dust. Each egg undergoes segmentation within its shell, and gives rise to a six-hooked larva, which consists of a spherical mass of cells provided with six protruding hooks of chitin. In this condition the eggs may be taken into the stomach of a grazing ox; in which case the larvae will issue from their shells, bore their way through the wall of the stomach or intestine of the ox, and come to rest in some organ, usually in the muscles, where they further develop into cystic larvae. In the process of development, a cavity appears within the solid ball of cells, the six-hooked larva therefore becomes a cyst, which grows considerably in size. At one point on the wall of the cyst a cup-like depression appears. Upon the inner surface of this depression, which is of course continuous with the outer surface of the cyst, four suckers are developed, and in many species a circle of hooks also. In this way the head or scolex of the mature worm is developed so that it lies within the cyst, which is embedded among the muscle fibres of the ox. If a cyst is swallowed by man, the head or scolex becomes everted, so that it assumes the mature condition, although it is still attached to the cyst by a short neck. The scolex buries itself in the wall of the intestine of the man; the attached cyst becomes dissolved, but the substance of the neck increases rapidly and becomes segmented, so as to form a mature tape-worm. The cystic stage is not wholly confined to the

ox, it may occur in other animals, and even in man. Since a cyst can establish itself in any part of the body of the host, it may do so in a vital organ, and become a source of danger.

In some species of Taenia the cyst is very large. Taenia echinococcus is a small tape-worm which commonly lives within the intestine of dogs. The cystic larva is like a big bladder, and is large enough to contain a pint or more of fluid; attached to the inner wall of the cyst is a vast number of heads or scolices; floating in the fluid are a large number of subsidiary cysts, which vary from the size of a pea to that of a hen's egg. The outer walls of these smaller cysts are also covered with innumerable scolices. The cystic stage of T. echinococcus is commonly found in sheep and goats, most frequently in the liver, for these animals while grazing may swallow the eggs of the Taenia which have been evacuated by dogs. The life cycle is carried on with certainty in the following manner. A sheep is slaughtered and gutted, the liver is found to be full of cysts, and being unfit for human food is thrown away, to be devoured by dogs, in which the tape-worm is developed. In some parts of India nearly all the sheep and goats have cystic livers. The cyst of Taenia echinococcus is sometimes found in man, and is then spoken of as an "Hydatid." Such cysts may grow for years, and finally cause death. Man is infected by eating uncooked vegetables which have been contaminated by dogs. Contamination can easily occur, as the minute eggs of the tape-worm are very

numerous, and are protected from heat and drought by the thick chitinous shell. Hydatid disease occurs among men in nearly all countries, but it is not common, except in Australia and Iceland.

Taenia coenurus is a tape-worm which is also found in dogs; it is much longer than T. echinococcus. The cystic stage is found in sheep, and causes a fatal disease called "staggers." Although the larval cyst is only about an ounce or two in capacity, being much smaller than that of T. echinococcus, it seems to choose out the brain of the sheep as the seat of its growth, hence its danger. This parasite causes great loss to owners of sheep in many parts of the world; it is common in Bengal. A remarkable occurrence in the life-history of both these species of Taenia, is the production by asexual means of a vast number of scolices out of one cyst, which is derived from a single fertilized egg, or zygote. This process reminds us of the lif
Distomum, in which there is an asexual m
of larvae.

NEMATODA

The Nematodes are cylindrical, unsegmented worms which are for the most part parasitic; several of them are parasitic in man. All Nematodes are covered with a particularly thick cuticle. There is no system of blood-vessels. The nervous system and excretory system are of a peculiar type. The sexes are separate; as a rule, the male is smaller than the female. Cilia have never

been seen in any Nematode; this is remarkable. Owing to their power of producing movement in fluids, cilia are of the utmost importance in the animal economy, and occur in every group of the animal kingdom except the Nematodes and Arthropods. Although Nematodes are very common, it is not always easy to obtain any one kind in large quantities. The large "round worm" Ascaris, which is found commonly both in horses and in man, is a good type for dissection, but it is not always easy to obtain. A small worm of the genus Oxyurus is very common in the intestine of the common cockroach. In Calcutta, almost every cockroach is infected with a dozen or more of these parasites, which are so translucent that most of the important features of their anatomy can be seen in the living state with the help of the microscope.

Oxyurus.—The contents of the intestine of a cockroach should be mixed with salt solution in a capsule. The worms will be seen as delicate white threads about one-quarter of an inch in length, which move, slowly bending themselves from side to side. A worm should be placed in a drop of salt solution upon a slide, covered with a slip, and examined in the living state; it is not easy to make permanent stained preparations of these worms, for the cuticle will not allow the preservative fluids to penetrate. Several species of Oxyurus have been described from cockroaches. The chief peculiarity of the genus is the long style-like prolongation of the body.

Examination.—Notice first the styliform process which marks the posterior end of the worm. The whole body is covered with a thick cuticle, which is distinctly annulated. The rings are most noticeable at the anterior end. The mouth is terminal, but the anus opens on one side of the base of the styliform process. The side upon which it opens is considered to be ventral; it is important to recognize this, because the generative and excretory apertures of the body are also upon the ventral surface.

The Alimentary Canal.—This is a tube which lies evenly between the mouth and the anus. In the anterior part of the body it shows three enlargements, which may be called the pharynx, gizzard, and stomach. The pharynx is more or less pear-shaped, but varies in form from moment to moment, because the animal has the habit of protracting and retracting the anterior end of the body. The gizzard is spherical, its walls are thick, and provided with a set of chitinous crushing plates, or teeth, which move in a rotatory manner, so that food material is ground between them; the action of the teeth should be watched—such teeth are rare among Nematodes. The stomach is a spherical chamber which is considerably larger than the gizzard. The intestine passes straight from the stomach to the anus. The individual cells which make up the walls of the gut and their nuclei are easily visible under the high power of the microscope. There are a number of muscle fibres, attached to the body wall opposite to the anus, which converge to a point on the ventral body wall just

behind the anus. The function of these is probably to open the anal aperture.

The Body Cavity.—There is a wide space between the gut and the body wall which is largely occupied by the generative organs. This space is called the body cavity, but it is not a true coelom, for it is not lined by a coelomic epithelium, and has not any of the other characters of a coelom. The individual endodermal cells of the intestine can easily be seen; they are not covered by any mesodermal tissue. The outer boundary of the body cavity is the body wall; this consists of an outer layer, or epidermis, which secretes the annulated cuticle, and of a number of large muscle fibres, which are placed longitudinally and cling to the inner side of the epidermis. The epidermis is remarkable, as in all Nematodes, because cell outlines can neither be seen in it nor brought into view by any method of staining; it consists simply of a thin layer of protoplasm in which nuclei are embedded. In Oxyurus the number of muscle fibres is eight, each of which reaches from one end of the body to the other; they are placed in adjacent pairs, one pair in each quadrant of the body, and are best seen towards the anterior end of the worm.

The Generative Organs.—The larger worms, such as are most suitable for examination, are all females. The generative organs lie loose in the body cavity, and nearly fill it. They consist of two elongated ovaries of equal length, which meet together in an oviduct, just as the divergent limbs of the letter Y meet together in the

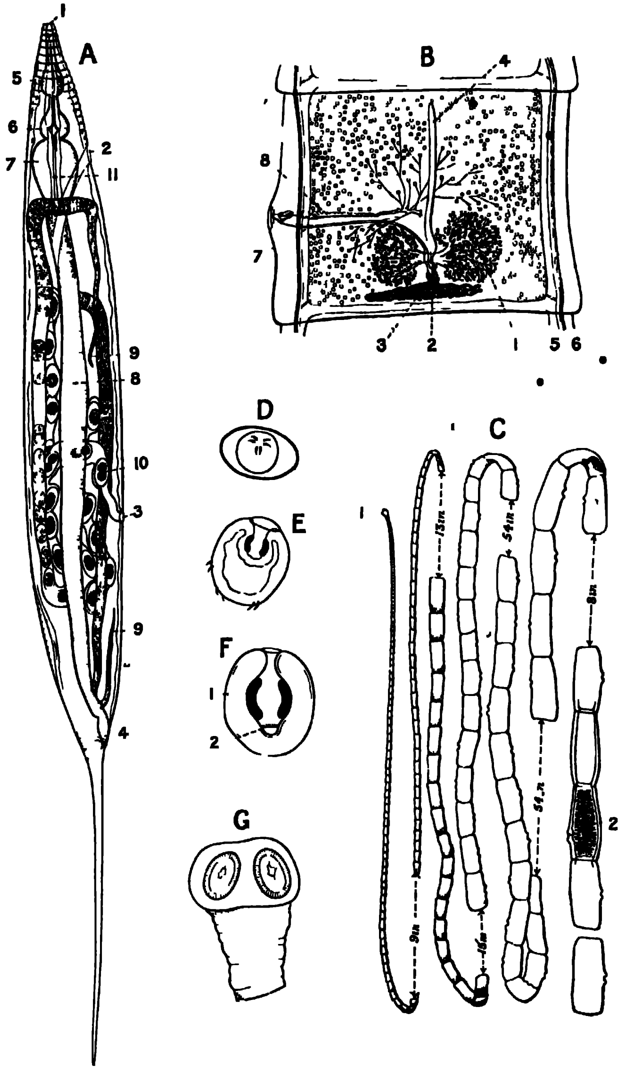

Fig. C is copied by kind permission of Messrs. Macmillan and Co., Ltd., from the "Cambridge Natural History."

PLATE VI.

THE NEMATODE (Oxyurus) AND THE TAPEWORM (*Taenia saginata*).

A. The Nematode Oxyurus from the intestine of a cockroach, female 1. mouth; 2. excretory pore; 3. generative pore; 4. anus; 5 pharynx; 6. gizzard (with teeth); 7. stomach; 8. intestine; 9. end of an ovary; 10. a segmenting ovum in the oviduct; 11. longitudinal muscle fibre × 30.

B. Mature segment of Taenia saginata. 1. ovary; 2. yolk gland; 3. shell gland; 4. uterus; 5. excretory duct; 6. lateral nerve; 7. vagina; 8. vas deferens (from Sommer).

C. Taenia saginata. 1. head; 2. a terminal segment containing a complex uterus full of ripe eggs (copied from the "Cambridge Natural History").

D. The six-hooked larva of a cestode.

E. Early development of the cysticercus.

F. Later development of the same. 1. sucker; 2. hooks.

G. Head of Taenia saginata × 20.

Figs. D, E, and F are diagrams.

vertical stem of the letter. The oviduct opens upon the ventral surface of the body, about halfway between mouth and anus. The ends of both ovaries should be sought for; they generally lie apart from one another. Each ovary ends in a pointed extremity, which is composed of undivided granular protoplasm, but further and further from the extremity the substance of the ovary becomes more and more clearly divided to form the eggs. Near the oviduct the eggs appear fully developed and surrounded by an oval shell. Fertilization takes place within the body of the worm, probably before the formation of the shell. Segmentation often commences while the eggs are still in the oviduct; extrusion of the eggs may often be observed. The males are less than a quarter of the size of the females; the testes are disposed much in the same way as the ovaries in the female.

The Excretory System.—This consists of two tubular channels which lie in the body wall, one on either side. At the level of the stomach these tubes leave the body wall and come together in the median plane; they open by a single short duct in the mid-ventral line. The aperture is elongated, and is less conspicuous than the opening of the oviduct.

Nervous System.—The nerves of Oxyurus are very difficult to see. In most Nematodes there is a nerve ring, which encircles the oesophagus near the mouth. Six nerves arise from this ring and pass to the hinder end of the body lying in the body wall: one of these lies in the mid-dorsal line, another in the mid-ventral

line; the others lie, a pair on either side, in close connection with the excretory ducts.

OTHER NEMATODES.—Many Nematodes are parasitic in man. Species of Ascaris, Oxyurus, Trichocephalus, Ancylostomum occur in the intestines of man. The dangerous parasite Trichina spiralis infests the muscles. Filaria medinensis, the guinea worm, is common in some parts of India; it occurs in the connective tissue, usually of the legs. Another species of Filaria is associated with

CHAPTER V

THE MOLLUSCA

The Molluscs form an important division of the animal kingdom. Most of them live in water, but some are terrestrial. Their bodies are soft, and are usually protected by a hard, calcareous shell, which is secreted by the animal. The organs of the body occur singly or in pairs; true segmentation does not occur in the group, and repetition of like parts in series is unusual. The presence of a mantle and of a foot are characteristic. The mantle is a soft curtain of tissue enclosing a mantle cavity, in which lie the organs of respiration, the gill, gills, or lung. The anus, kidneys, and generative ducts usually open into the mantle cavity. The edge of the mantle is thickened and is closely attached to the growing rim of the shell, which is added to by the secretive power of the cells of the mantle's edge. The outer surface of the mantle is applied to the inner surface of the shell. The foot is a tough mass of muscular tissue, which lies below the level of the mouth and is used in locomotion. There is a well-developed heart lying in a space lined by epithelium, which is called the pericardium. The heart consists of a ventricle and one or two auricles. The

auricles receive blood from the respiratory and excretory organs, and pass it to the ventricle, from which it is pumped to the tissues. In many Molluscs the pericardium communicates with the outer world by means of excretory tubes or nephridia, and the generative organs are developed from the epithelium of the pericardium, which is therefore considered to be a coelom. The nervous system consists of ganglia linked by connective nerves. There is always a pair of cerebral ganglia lying above the oesophagus, a pair of pedal ganglia in the foot, and others connected with the viscera. The two largest groups of the Molluscs are the Lamellibranchia and the Gasteropoda.

Lamellibranchia.—These Molluscs are all aquatic; they have no definite head, the gills are leaf-like in form, and net-like in structure. Most of the Lamellibranchs are bilaterally symmetrical, that is to say, the shells, mantle-flaps, gills, kidneys, auricles of the heart, ganglia, and nerve connectives occur in pairs, each member of which is similarly situated on either side of the median plane of the body.

Gasteropoda.—Most of the Gasteropods live in water, but those which belong to the order of Pulmonates live on land. They have a definite head provided with tentacles and eyes. The foot has a flat sole, upon which the animal creeps. Rising from the upper surface of the foot is the head, and behind it the visceral mass and mantle, both of which are concealed within the shell. The Gasteropod Molluscs differ from nearly all

other animals in not being bilaterally symmetrical; they cannot be divided by a median plane, so that one half resembles the other. The head and foot are symmetrical, but the shell and visceral mass are unsymmetrical. Another peculiar feature of their anatomy is that the anus opens in the same direction as the mouth; in most animals it opens in the opposite direction. These peculiarities have been explained in the following way: Gasteropods are the descendants of Molluscs which, like the Lamellibranchs, were symmetrical, with mouth and anus opening in opposite directions. The nephridia, the auricles, the gills, and the visceral nerves were originally in pairs, placed posteriorly and symmetrically on either side of the rectum. In the process of evolution the intestine underwent a displacement, so that the anus moved first to the right side of the animal and then to the front. The gills and kidneys kept their close relation with the rectum in spite of its displacement. In consequence, those organs which were originally on the right side of the rectum must necessarily have passed over to the left side when the rectum moved to the front. Before the right gill and kidney were able to take up their new position on the left, they must have passed over the anterior part of the intestine; the visceral nerves moved with them. We find in many Gasteropods that only one gill and one kidney are present, and that the visceral nerve, which is associated with them, arises from the right pleural ganglion and passes over the intestine to its destination, while the corresponding nerve of the

other side passes obliquely below the intestine; it is therefore supposed that the single gill of most Gasteropods represents the right-hand one of a pair which were placed posteriorly and symmetrically on either side of the rectum in Molluscs which have long since become extinct.

FRESH-WATER MUSSEL (*Unio marginalis*)

Fresh-water mussels are common in the tanks of Bengal; they are found in an upright position half buried in the mud. They occasionally move slowly by means of the foot, which can be protruded between the shells. They obtain food by straining small organisms from the water by means of their net-like gills. The sexes are separate, but they do not come together; fertilization is effected through the water. The young are hatched and reared up to a certain stage between the layers of the mother's gills.

EXTERNAL APPEARANCE.—Nothing can be seen externally except the hard shell, which is oval in shape and consists of two similar halves, or valves, united by a dorsal hinge. One end of the shell is more rounded than the other, and is called anterior, for the mouth is directed towards it; the pointed end is posterior, for the rectum is turned that way. On either side of the hinge is a raised point called an umbo, which is opposite to its fellow. These points are the oldest parts of the shells which protected the mussel when it was very small.

The growth of the shell takes place at the margin. Many curving lines can be seen on the shell parallel with the margin, and converging towards the umbo of the same side: these are the lines of growth; they are caused by temporary cessation in the growth of the shell at successive periods in the life of the mussel.

INTERNAL ANATOMY.—Molluscs should be killed by keeping them overnight in a weak solution of chloral hydrate; if treated in this way they die in a relaxed state. When the animal is dead the valves of the shell gape open slightly. The anterior adductor muscle, which stretches between the valves and keeps them closed, is very near the margin of the rounded end; it must be separated from the shell on one side by pushing the handle of a scalpel between the mantle and the shell. The mantle is the soft layer which adheres to the inner side of the shells. The posterior adductor muscle, which is near the posterior end, should be treated in the same way; the valves will then gape widely owing to the elasticity of the hinge. Break off one valve after separating the mantle from it, and leave the animal in the other. Pass a pin through the ligament of the hinge, and fix it in a dish, beneath water. Examine the inner surface of the detached valve: it is pearly; there are two oval marks upon it where the adductor muscles were attached. Two straight lines embrace each of these marks, and converge towards the umbo; they are the boundaries of the path along which the muscles moved as the animal grew. Before it was detached the mantle

was in contact with the pearly surface of the shell, and the margin of the mantle was firmly adherent to the margin of the shell. The cells of the mantle secrete particles of chalk within their substance, and add them to the shell; in this way the shell grows. Break off a piece of shell and examine the fracture; there are three layers in it: a thin outer horny layer, a thick middle layer consisting of minute columns of calcium carbonate set close together, and an inner pearly layer. The two outer layers are formed by the margin of the mantle; the pearly layer is formed subsequently by the surface of the mantle. The pearly layer often contains raised pearl-like points; these are caused by foreign bodies such as sand, which led to irritation and became enclosed within the pearly secretion of the mantle. Sometimes spherical pearls are found wholly embedded in the soft tissue: these are due to parasites which have become coated with the pearly secretion. Such pearls are rare; they are occasionally of value. Valuable pearls are more often the products of oysters, which live in the sea

Description of Soft Parts.—When the animal is living and undisturbed the edges of the shell are slightly apart, but the edges of the mantle-flaps are in contact. The mantle cavity is entirely closed in this manner, except at the posterior end, where the mantle edges lose touch to form a gap which allows the entrance and exit of water. The posterior ends of the gills are united with the margin of the mantle, and divide this gap into an upper and lower aperture. The upper one is called the exhalent

aperture. The lower and larger of the apertures is fringed with short tentacles, which spring from the mantle's edge; it is called the inhalent aperture, because a current of water passes through it into the mantle cavity. The gills lie in the mantle cavity; the current of water passes through their meshes and along certain channels which lie above the gills and are continuous posteriorly with the cloaca. The cloaca is a chamber which lies below and behind the posterior adductor muscle; it receives the anal contents as well as the generative and excretory products, which find their way into it along the suprabranchial channels. The current of water finally leaves the cloaca through the exhalent aperture. The water is caused to move in this direction by cilia, which fringe the meshes of the gill.

Cut off the mantle, and observe the line of its attachment.

The Mantle Cavity.—After removal of the mantle a large cavity is exposed which contains the visceral mass, the foot, the gills and the labial palps. The mouth opens into this cavity behind the anterior adductor muscle, between it and the foot. The labial palps are a pair of triangular flaps attached to the visceral mass behind the mouth, and just below the attachment of the mantle; the palps of either side are continuous with one another anteriorly—the outer palps are continuous in front of the mouth, the inner palps are continuous behind it. Grains of food material can sometimes be seen between the palps; they move forwards owing to the

action of cilia, and pass sideways into the mouth. The gills are a pair of flat organs which are striped vertically. They are attached behind to the posterior margin of the mantle; in front they lie in a pocket of the mantle, which is formed by a sudden downward curve of its line of attachment. Each gill consists of two layers or lamellae, an outer and an inner, which may be separated from one another with ease. In order to see how the gills are fixed, they should be cut off with scissors close to their attachments. The attachment of each lamella should be examined separately; they are disposed as follows:—

Outer gill	Outer lamella.	To the mantle in its whole length.
	Inner lamella	These are attached together to the under side of the kidney in its whole length. The kidney does not extend further than the posterior adductor muscle; behind this muscle the two lamellae are joined together in a free margin, which is curved, and may be called the lateral conjoined margin.
Inner gill	Outer lamella	
	Inner lamella.	Is attached in front to the visceral portion of the foot; behind the foot it is united with its fellow of the opposite side in a free margin, which may be called the median conjoined margin.

The three conjoined margins of the gills, two lateral and one median, lie in the floor of the cloaca. In the

closely allied genus Anodon, the inner lamella of the inner gill is attached to the visceral portion of the foot for a short distance only.

The excretory and generative apertures must now be looked for; they lie close together, far forwards between the attachments of the lamellae of the inner gill. The aperture of the kidney has a white margin, and is therefore easy to see; it lies above and behind the generative aperture. A lamella of one of the gills should be examined under the microscope.

Alimentary System.—The mouth leads into a short oesophagus which lies close behind the anterior adductor muscle and opens into a large irregular cavity, or stomach, which lies embedded in the soft, brown substance of the liver. The inner surface of the stomach receives the mouths of several tubular crypts, which are excavated in the liver and convey the hepatic secretion into the stomach. There is a tongue-like protuberance in the floor of the stomach; behind it is the opening of the intestine, which scarcely differs in appearance from the openings of the crypts. The intestine passes downwards in a posterior direction through the visceral mass; it turns upwards and downwards twice before finally leaving the visceral mass and becoming the rectum. The last part of the intestine lies parallel with and close behind the first part, and contains a ridge, or typhlosole; it comes in contact with the liver, and passes suddenly in a posterior direction through the pericardium, in which it is

embraced by the ventricle of the heart. After leaving the pericardium it passes dorsal to the posterior adductor muscle, and opens into the cloacal chamber. The anal aperture is kept closed by two side flaps.

Nervous System.—There are three pairs of ganglia named respectively Cerebral, Pedal and Visceral, which are united by nerves. The ganglia can be found easily by searching in the right places. The two cerebral ganglia are placed widely apart. To find the cerebral ganglion of one side. grasp both labial palps with forceps just behind the spot where they separate at the angle of the mouth; cut them from their attachment at this spot. The ganglion will be disclosed, lying in a small sinus of the connective tissue; it gives off three principal nerves, one in front of the mouth to join its fellow of the opposite side, one posteriorly and downwards to join the pedal ganglion, the third posteriorly and upwards towards the visceral ganglion. The pedal ganglia lie together in the generative organ close to the muscular part of the foot. To see them, remove the animal from its shell and fix it upon its back with the foot uppermost; split the foot exactly in the middle line until the muscular substance is completely divided, carry the division a very little further into the substance of the generative organ; the pedal ganglia will then be exposed. They lie together near the junction of the anterior and middle thirds of the length of the foot; they are orange in colour, and give off six lateral branches, the foremost of which are the cerebro-pedal connectives, and join

the cerebral ganglia. The visceral ganglia lie together beneath the posterior adductor muscle; in order to see them, remove the mucous membrane which covers the lower side of the muscle. These ganglia are elongated bodies, and are larger than either of the others; from their anterior end they each give off two large nerves, one of which is the cerebro-visceral connective, and passes straight forwards through the substance of the kidney to join the cerebral ganglion; the other enters the lateral conjoined margin of the gills, which is suspended from the under side of the adductor muscle, and is reflected in a posterior direction.

Heart and Pericardium.—The pericardium lies close to the hinge of the shell; it is a cavity in which the heart and rectum lie. A cut made in the soft tissues close below the hinge will lay it open. The pericardium is lined by epithelium, and is in communication with the outer world through the nephridial tubes. In order to see the pericardial openings of the nephridia, cut through the rectum anterior to the heart, and pull the cut ends forward. Two openings will be seen at the anterior end of the pericardium; they lie beneath the rectum at the spot where it enters the cavity. The rectum passes through the pericardium from end to end, and is embraced by the ventricle of the heart. The ventricle is ovoid in shape, and of a brown colour. The two auricles which join it, one on either side, have transparent membranous walls, and are triangular in shape; the apex of the triangle is

joined to the ventricle, and the base is directed outwards towards the attachments of the gills. The auricles receive blood directly from the gills; their close relation to the gill attachments should be noticed. Blood passes from the auricles into the ventricle; it is prevented from returning by means of valves. The veins and the course of the circulation in the closely allied genus Anodon have been described in the following words: "The veins, except the largest ones, cannot be dissected without injecting them, and even then they are difficult to follow. They may, however, be identified in sections of hardened specimens. The vena cava is a median longitudinal vessel lying beneath the floor of the pericardium; it receives, in front, large veins returning blood from the foot and visceral mass, and behind, much smaller vessels from the posterior part of the body. The afferent branchial veins are a pair of large vessels running along the lines of attachment of the outer and inner gills to each other. Vessels arise from them which carry blood to the gills. The efferent branchial veins run along the bases of the outer lamellae of the outer gills; they return to the auricles the blood from the gills, and also receive at their anterior and posterior ends large vessels returning aerated blood from the mantle-lobes. The ventricle receives arterial blood from the auricles, and drives it through the arteries all over the body. The blood from the foot and viscera is returned to the vena cava, from which it passes through the kidneys to the gills. From

the gills it is returned by the efferent branchial veins to the auricles. The blood from the mantle-lobes is returned direct to the auricles, and does not pass through either the kidneys or the gills. The circulation is in great part carried on through irregular channels, or lacunae" (Marshall and Hurst's "Practical Zoology" (Smith Elder & Co.)).

The Excretory Organs.—These consist of a pair of nephridia, or excretory tubes, each of which is open at both ends. They are brownish-black in colour, and lie side by side between the pericardium and the visceral portion of the foot. Their posterior ends touch the posterior adductor muscle. The internal and external openings of the nephridia have already been examined; the former is in the pericardium, the latter is between the attachments of the inner gill. Each nephridium consists of two parts, the kidney proper and the ureter, both of which are tubular. The kidney lies below the ureter, and extends from the pericardial opening to the posterior adductor muscle. The ureter lies above the kidney, and is continuous with it behind; it opens in front by the external aperture which has been seen. In other words, the kidney and ureter together form a single tube which is bent once upon itself. The wall of the kidney is black and shreddy, but that of the ureter is smooth. The ureters are connected by a wide duct which crosses the median plane.

THE POND SNAIL (*Ampullaria globosa*)

This Mollusc is common in the ponds of Bengal. It is most active at the commencement of the rains, when it breeds. The female is nearly twice the size of the male; in the month of July they are found in pairs, close to the water's edge. After separation the female crawls out of the water, and deposits a mass of about fifty eggs on the banks of the pond. The eggs contain a large quantity of colourless albumen, and are surrounded by a fragile white shell. The ovum is a minute speck floating in the albumen. In about three weeks it develops into a young snail, which leaves the shell in the adult form. Observation of the living creature should be made while it is in a glass vessel; if the snail be left undisturbed, it may be seen to glide over the glass upon an oval grey surface, which is the sole of the foot. The head and visceral mass rise from the upper surface of the foot. The head bears a pair of eyes and two pairs of tentacles: the foremost, or cephalic tentacles are prolongations of the corners of the head; below them, in the middle line, is the opening of the mouth. Behind the cephalic tentacles are the true tentacles, which may be two inches in length in the extended condition; close behind the tentacles are the eyes, which are borne upon short stalks. If the animal be taken from the water, it forthwith draws the whole of the foot into the shell and closes the opening by means of the operculum, an oval calcareous plate which is attached to the upper surface of the

foot behind the viscera' mass. Behind the left eye is a deep cavernous hollow, which is bounded below by a fleshy shelf called the left syphon, and above by the border of the mantle, which is in close contact with the margin of the shell. Except on the left side, the border of the mantle is in contact with the region behind the head, which is called the neck. By the contact of the mantle's edge with the neck the mantle cavity is closed from the outer world. The mantle cavity is open on the left side to allow air to pass into the lung; the opening of the lung is often visible within the mantle cavity. Hanging from the under surface of the mantle, in front of the opening of the lung, is the osphradium, a structure which somewhat resembles a comb, and is believed to be an organ of taste. When the animal is undisturbed the left syphon may be furled into a tube, an inch in length. Ampullaria differs from other Gasteropods in having alternative methods of respiration. It has both a lung and a gill, either of which may be brought into use according to circumstances. When the snail is in shallow water, or comes on to the land to lay its eggs, it breathes air with the lung; but, on the other hand, it may remain in the depths of the pond, and never come to the surface for air; in this case the aperture of the left syphon is kept closed, and a similar aperture appears on the right side between the neck and mantle. This aperture is bounded by a right syphon, which is similar to the left one but less prominent. Water passes through this aperture, and gives up its dissolved oxygen to the

gill. The student must remember that the vast majority of Molluscs have one or other method of respiration, not both. Ampullaria is quite exceptional in its alternative respiration. It is convenient as a type because it is of large size and is easily obtained.

DISSECTION. Before being dissected the snails should be kept overnight in a weak solution of chloral hydrate. The shell should be snipped off with strong scissors, and the operculum separated from the foot. The animal should be pinned down under water upon its foot. The success of the dissection much depends on the direction of the first cut, which should be made in the following way: find the lower end of the gill beneath the edge of the mantle, and cut through the mantle along the left side of the gill in its whole length. On turning the flaps outwards, the entire mantle cavity will be exposed. On the floor of the mantle cavity is a prominent dividing ridge which ends in front by joining the right syphon. On the left of the ridge is the lung and osphradium; on the right is the gill, the rectum, and generative duct, and a small part of the kidney.

Contents of the Mantle Cavity. The gill is attached to the mantle, and extends from beneath its edge on the right to the posterior corner of the mantle cavity. It consists of a single series of lamellae attached to an axis which contains a blood-vessel. The rectum is a tube lying in the floor of the mantle cavity; it opens in front within the right syphonal aperture; the anal opening is surrounded by eight small papillae. On the left side of

the rectum, between it and the dividing ridge, is the generative duct. In the female this is as thick as a man's little finger; it opens by a small slit upon a papilla which lies close to the anus. The kidney can be recognized by its reddish-brown colour. A small part of it projects into the hinder part of the mantle cavity, but the greater part of the organ is in the visceral mass posterior to the mantle cavity. The kidney must be examined carefully in order to find its aperture. There is a small crypt below that part of the kidney which lies in the mantle cavity; the slit-like aperture of the kidney lies in this crypt. In order to see it properly, the kidney must be detached along one side and turned over; it can easily be demonstrated by injecting carmine into the cavity of the organ with a hypodermic syringe.

The lung is a large bag with spongy walls attached to the mantle; it has a large oval opening, which looks towards the left syphonal aperture. The osphradium is attached to the mantle in front of the pulmonary opening; it is pectinate or comb-like in appearance.

The Heart and Pericardium.—The posterior end of the gill is directed towards the heart, which can be dimly seen through the roof of the pericardium. The heart consists of one auricle and a ventricle. The auricle is a thin-walled sac which lies to the right of the ventricle and receives veins from the gill and kidney; it opens into the ventricle. The ventricle has thick muscular walls; the opening between it and the auricle is guarded by a pair of valves, which are like the side pockets of a man's coat.

and prevent the blood returning from the ventricle to the auricle. If coloured fluid be injected into the cavity of the ventricle it will not pass into the auricle. On the left the ventricle gives out the aorta, which bifurcates at once. One division passes backwards to the visceral mass. The other dilates into a large ampulla, which is about half the size of the ventricle; from this division various arteries are given off to the head and foot. The walls of the aortic ampulla are peculiar in appearance; they contain white patches of what is probably lymphoid tissue. If the ampulla be injected the fluid will not pass into the ventricle. Few Molluscs possess this curious organ. The pericardium is a closed sac lined by epithelium; it does not communicate with the nephridium in Ampullaria.

The Nephridium. This is a brownish organ of triangular shape, the larger part of which lies superficially in the visceral mass, posterior to and to the right of the pericardium. The anterior end and the aperture of the organ are in the mantle cavity, where they have been examined.

DISSECTION. Divide the skin with scissors in the middle line of the head, and continue to cut backwards along the neck and floor of the mantle cavity, being careful to preserve the supraintestinal nerve, which crosses over the oesophagus in the neck.

The Alimentary System.—The mouth leads into the buccal mass, which contains an apparatus for grinding the food. Mastication is performed by the mandibles

and the radula. To see these structures the roof of the buccal cavity must be opened in the middle line. The mandibles are a pair of chitinous plates lying in the side walls; the radula, which is covered with teeth like a file, is exposed in the middle of the floor of the cavity. The radula is continuous on either side with an oval plate of smooth chitin, which is in contact with the jaw of the same side. The buccal mass lies symmetrically in the median plane, but the oesophagus passes obliquely to the left of that plane. The salivary glands are two small round bodies which lie one on either side of the oesophagus near its commencement; each opens by a short duct into the roof of the buccal cavity. The oesophagus passes posteriorly towards the visceral mass, where it opens into the stomach. It must not be disturbed at this stage of the dissection, lest two important nerves, which lie above it, should be broken. The stomach lies superficially in the lower and left side of the visceral mass; it can easily be recognized by its rosy colour. It should not be disturbed until the intestine has been examined.

The upper surface of the visceral mass, which lies behind the pericardium and kidney, is of a yellowish-brown colour; if a cut be made in this surface, it will be seen that there is a large cavity beneath it, in which lies a coil of the intestine and the generative organ. This cavity, which may be referred to as the visceral cavity, must now be laid open; its upper wall is thick, and has a shreddy, glandular appearance, somewhat like

the interior of the kidney. The organs which lie within the visceral cavity are smooth, as though covered by epithelium. The visceral cavity is not a coelom; until the method of its development is known, we cannot be sure as to its nature. It can be shown by injection that this cavity does not communicate with any organ, or with the exterior.

The coil of intestine which lies in the visceral cavity should be unravelled; it is continuous on the one hand with the rectum, and on the other with the anterior aspect of the stomach. The oesophagus and intestine enter and leave the stomach side by side. When this fact has been observed, the stomach should be opened. The interior of the organ is complicated by the folding of its walls; the epithelium, which lines the greater part of it, is of a rosy colour, as though it has been stained lightly with carmine.

The liver is in two parts, or lobes. The right lobe is much larger than the left, and forms a considerable part of the visceral mass, including the apex of the spire. The broadest part of it is applied to the stomach. The left lobe of the liver lies in the visceral cavity; it is much smaller than the right lobe, and is also in contact with the stomach. The substance of the liver is soft and friable; it may be light yellow or greenish-black; it is traversed by a ramifying system of white tubes, which convey the secretion to the stomach. These ducts open into the stomach by several apertures.

The Generative Organs.—The sexes are separate; the

females are about twice the size of the males. In the mature female there is a small ovary and a large albumen gland, both of which lie in the visceral cavity. The albumen gland is a rounded body, resembling in colour the yolk of an egg; it may be nearly an inch in diameter. The ovary is a small rugose organ about the size of a pea, which projects from the left side of the albumen gland. The oviduct and its aperture have already been examined in the mantle cavity. In the male the testes somewhat resemble the ovary in outward appearance; there is no albumen gland, and the generative duct is much narrower. Both male and female are provided with a copulatory organ, which is alike in form in both sexes, but not in size: in the male it is much larger than in the female. This organ is situated upon the edge of the mantle opposite the generative opening; it consists of a curved and pointed flagellum, which is hidden within a deep groove or sheath.

The Nervous System.—The nervous system should be traced with the help of the diagram. The cerebral ganglia lie on either side of the buccal mass near the base of the tentacles, and are connected by a strap-like nerve. They supply nerves to the tentacles and to the eyes, and also a small filament to the small buccal ganglia, which lie upon the upper surface of the buccal mass in contact with the salivary duct. After the cerebral ganglia have been examined, the oesophagus should be cut through at the place where it is crossed by the supraintestinal nerve; the anterior end should

be raised and turned forward over the mouth, and fixed in that position with a pin. The pedal and pleural ganglia of either side will then be displayed; although they are closely united, they can easily be distinguished from one another. Each ganglion is connected by a stout nerve with the cerebral ganglion of the same side. The pedal ganglia are connected across the median plane by a short, stout nerve. On the outer side of the pedal ganglia lie the otocysts; one of them should be removed and examined under the microscope. An otocyst is a spherical vesicle, which is full of oval calcareous bodies called otoliths. The supraintestinal nerve, which has already been seen, is a connection between the right pleural ganglion and the supraintestinal ganglion. The pleural ganglia are connected by a slender subintestinal nerve; in many Molluscs this nerve passes from the left pleural ganglion direct to the subintestinal ganglion; but in Ampullaria it proceeds to and from the right pleural ganglion in its course to the subintestinal ganglion, which is very small and lies to the right of the oesophagus. Both the pleural ganglia send off a stout pallial nerve to the mantle, and the left ganglion sends a nerve which at first lies with the left pallial nerve, but soon leaves it to join the supraintestinal ganglion. The visceral ganglion lies beneath the skin of the mantle cavity close to the heart; it sends nerves to the viscera, and is connected with the subintestinal ganglion, and also with the supraintestinal ganglion by another nerve, which lies above the oesophagus.

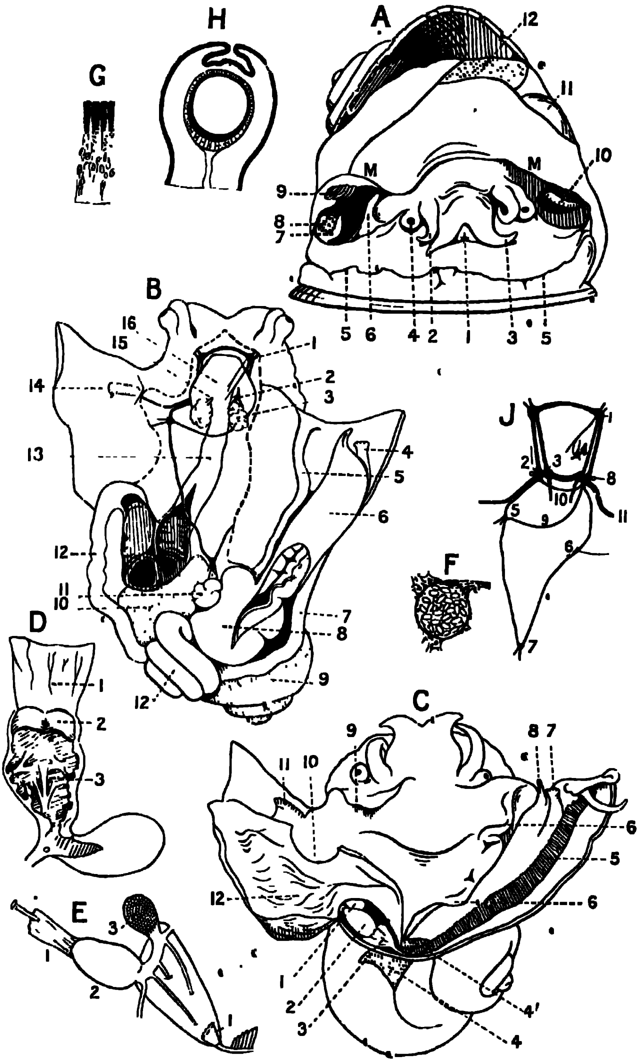

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PLATE VII.

THE POND SNAIL (*Ampullaria globosa*).

A. The animal resting upon the operculum, most of the shell having been removed. 1. the mouth, 2. the tentacle, 3. cephalic tentacle; 4. the eye; 5. a groove formed by the folding of the foot; 6. the dividing ridge of the mantle cavity; 7. genital papilla; 8. rectum, 9. end of the gill, 10. osphradium lying in front of the pulmonary aperture, 11. the pericardium, 12. kidney. MM. border of mantle.

B. The floor of the mantle cavity has been divided, the heart removed, the visceral cavity opened, and the viscera separated from one another. 1. cerebral ganglion, 2 buccal ganglion, 3. salivary gland; 4. anus; 5. dividing ridge; 6 oviduct, 7. rectum; 8. albumen gland; 9. right lobe of liver, 10, L. lobe of liver; 11. ovary; 12. intestine; 13. oesophagus; 14. osphradium; 15. salivary duct; 16 buccal mass.

C. Contents of mantle cavity and pericardium. 1. aortic ampulla; 2. ventricle, 3. auricle, 4. kidney, 1'. portion of kidney lying in the mantle cavity; 5. gill, 6. dividing ridge, 7. anus, 8. genital papilla, 9. left siphon: 10. margin of the pulmonary aperture; 11. osphradium; 12. interior of lung.

D. The heart removed and cut open. 1. the auricle; 2. auriculo ventricular valves; 3. the ventricle.

E. Heart and pericardium. The auricle (1) has been cut through, and the ventricle has been turned out of the pericardium and over to the left; 2. ventricle, 3. aortic ampulla.

F. Otocyst × 20.

G. Section of the retina of the eye.

H. Diagrammatic section of the eye.

J. The nervous system. 1. cerebral ganglion, 2. pleural ganglion, 3. pedal g.; 4. buccal g.; 5. supraintestinal g; 6. subintestinal g.; 7. visceral g.; 8. otocyst; 9. supraintestinal nerve, 10. subintestinal nerve; 11. right pallial nerve.

THE LAND SNAIL (*Achatina fulica*)

It is believed that this snail, which is common throughout Lower Bengal, has been recently introduced into India from abroad. In some ways the land snail and pond snail are alike; only those features in which they differ from one another will be described.

There is no operculum, but the animal can withdraw into its shell and close the mouth of it with a film of dry mucus. The eyes are placed at the ends of the long tentacles, and can only be seen when they are fully protruded. The edge of the mantle is not free as in the pond snail, but is fused with the neck. The mantle cavity is completely closed except on the right side, where the pulmonary aperture is situated. On the right side of the neck, a short distance behind and below the right tentacle, is the generative opening.

DISSECTION.—The mantle cavity must be opened carefully. A cut should be made with scissors, commencing at the pulmonary aperture and directed forwards so as to separate the mantle from the neck. The opening of the rectum, which lies near the pulmonary aperture, should now be sought for; a second cut in the mantle must be made in an upward direction from the pulmonary opening alongside the rectum. The mantle can now be turned over to the left as a flap, so that the mantle cavity is fully exposed.

The Lung.—The inner surface of the mantle is spongy,

and covered with a network of large blood-vessels; it functions as a lung.

The Kidney.—This is a brown gland which is situated in the roof of the mantle cavity; it consists of two lobes, a large and a small, placed at right angles to one another. The ureter lies along the posterior margin of the organ, and leaves it at the apex of the lesser lobe. After leaving the kidney the ureter lies alongside the rectum and opens close to the pulmonary aperture.

The Heart and Pericardium. Between the anterior border of the kidney and the pulmonary surface is a large blood-vessel which receives many branches from those organs. This vessel, which is very wide and conspicuous, enters the auricle of the heart. The heart lies in the pericardium; it consists of an auricle and a ventricle, just as in the pond snail, but there is no aortic ampulla. The aorta leaves the right end of the ventricle, and after giving off a large branch to the visceral mass, passes towards the head: it can be seen externally as a ridge lying in the floor of the mantle cavity between two elevations, which are caused by the projection of the crop and the common generative duct. The aorta passes towards the head and enters a canal between the pleural and pedal ganglia; this will be seen at a later stage in the dissection. The skin of the head must be divided in the middle line, and the division must be continued along the neck through the thick adherent edge of the mantle and finally along the floor of the mantle cavity. This dissection will expose all the important organs not yet examined.

Alimentary System.—The jaw consists of a hard semi-calcareous body, shaped like a horseshoe, which is attached to the roof and side walls of the buccal cavity close to the mouth. The rough surface of the jaw can be seen through the mouth without dissection. There is a radula in the floor of the buccal cavity; its teeth are very numerous, and are of one shape. Food is grasped between the surface of the radula and the jaw. On the upper surface of the oesophagus immediately behind the buccal mass are the cerebral ganglia. Nerves pass from the cerebral ganglia to the tentacles, which are often inverted; these nerves must be distinguished from the retractile muscles of the tentacles, which meet together in a band lying across the oesophagus. Further back the oesophagus is dilated to form a crop, which is usually distended with brown fluid. Lying on either side of the crop are the lobulated salivary glands. The salivary ducts pass between the nerve ring and the oesophagus, and open into the buccal cavity. The crop becomes narrow behind, and opens into a large spherical stomach, which lies embedded in the liver. The secretion of the liver opens into the stomach by two bile ducts. The intestine leaves the stomach close to the spot where the oesophagus enters it, and after becoming twisted in the liver, passes into the mantle cavity, where it is usually referred to as the rectum.

The Generative Organs.—These organs are quite different from those of the pond snail, for the land snail is hermaphrodite. The ova and spermatozoa are

formed together in the hermaphrodite gland, a small white organ which is embedded superficially in the spiral lobe of the liver. The hermaphrodite gland can easily be recognized by its duct. The hermaphrodite duct is a narrow contorted tube, which opens into a much larger tubular organ called the common duct. The common duct contains two passages side by side; the one which is much lobulated conveys the spermatozoa, the other conveys the ova. At the junction of the hermaphrodite and common ducts, a large greenish-white organ called the albumen gland is attached. The common duct becomes divided anteriorly into two separate ducts, a vas deferens and an oviduct, which meet again at the common generative aperture. The vas deferens ends in a protrusible organ called the penis, which can be retracted by a muscle; the muscle of the penis is inserted into the wall of the vas deferens, which is bent into a loop when the organ is withdrawn. The penis and oviduct open together in the external generative aperture. The termination of the oviduct is somewhat enlarged, owing to the thickening of its walls. Close behind this thickening the oviduct receives a tube, which lies side by side with it and ends blindly in a small dilatation known as the spermatheca.

The Nervous System.—The cerebral ganglia should be separated from one another by cutting the connective which unites them; the oesophagus can then be raised and removed to one side. The pleural and pedal ganglia, which were hidden by the oesophagus, will

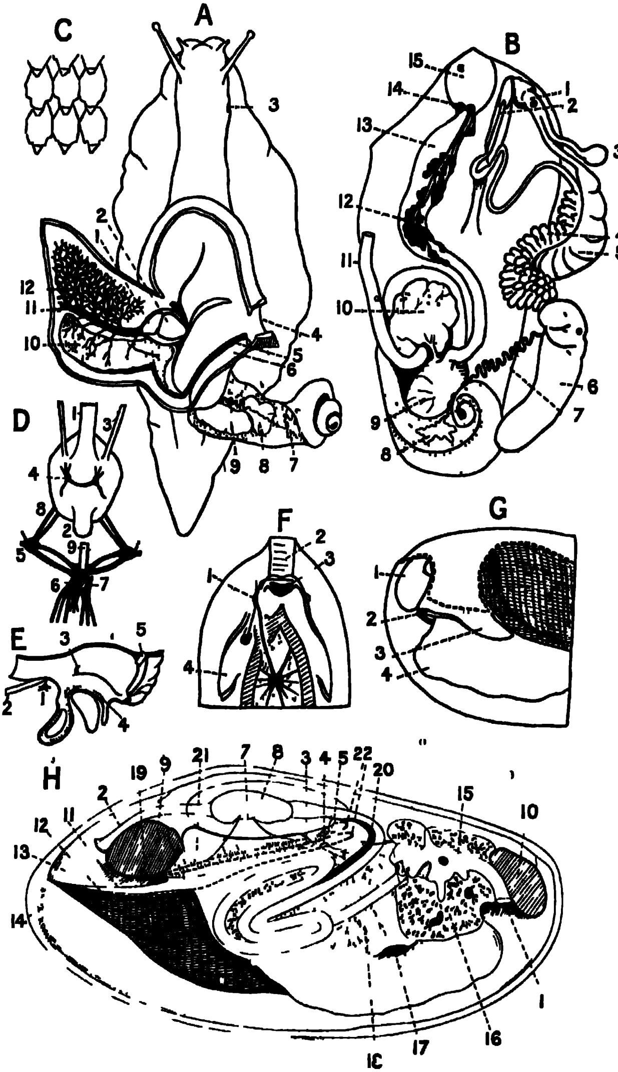

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PLATE VIII.

THE MOLLUSCS ACHATINA AND UNIO.

A—E. The Land Snail (*Achatina fulica*). F–H. The Pond Mussel (*Unio marginalis*).

A. 1. auricle of heart; 2. ventricle; 3. external generative aperture; 4. pulmonary aperture; 5. ureter; 6. rectum; 7. hermaphrodite gland; 8. stomach; 9. albumen gland; 10. kidney; 11. efferent pulmonary blood-vessel; 12. pulmonary plexus.

B. 1. oviduct; 2. penis; 3. spermatheca; 4 and 5. common generative duct; 6. albumen gland; 7. hermaphrodite duct; 8. hermaphrodite gland; 9. stomach; 10. left lobe of liver; 11. rectum; 12. salivary gland; 13. crop; 14. cerebral ganglia; 15. buccal mass.

C. Teeth of radula × 50.

D. The central nervous system, displayed in the following manner: the two cerebral ganglia have been widely separated from one another, their connective having been cut. The oesophagus has been cut through and pulled forwards so that the underside of the buccal mass is uppermost. 1. oesophagus; 2. radula sac; 3. salivary duct; 4. buccal ganglion; 5. left cerebral ganglion; 6. pleural ganglia; 7. right pedal ganglion; 8. labial nerves; 9. a portion of the cephalic blood-vessel.

E. Median section through buccal mass. 1. buccal ganglion; 2. salivary duct; 3. opening of the same; 4. radula; 5. the jaw.

F. The mussel removed from the shell and fixed with the foot uppermost and dissected to display the nervous system. 1. cerebral ganglion; 2. anterior adductor muscle; 3. mouth; 4. labial palps.

G. Anterior half of the mussel lying in the right valve of the shell. The dotted line indicates the line of attachment of the left mantle flap, which has been removed. 1. anterior adductor muscle; 2. the mouth; 3. the labial palps; 4. foot.

H. The mussel lying in the left valve. Mantle and gills of the right side have been removed. Organs represented diagrammatically. 1. mouth; 2. rectum; 3. excretory pore; 4. generative aperture; 5. renopericardial opening; 7. auricle of the heart; 8. ventricle; 9. posterior adductor muscle; 10. anterior adductor muscle; 11. lateral conjoined gill margin; 12. median conjoined gill margin; 13. cloaca; 14. tentacles fringing inhalent aperture; 15. stomach; 16. liver; 17. pedal ganglion; 18. generative organ; 19. visceral ganglion; 20. typhlosole; 21. communication between kidney and ureter; 22. anterior ends of gill attachments.

now be seen lying close together. Each ganglion is connected with the cerebral ganglion of the same side. The pleural and pedal ganglia are separated from one another by the passage of the main artery of the head. If the fine point of a knife be thrust into this passage, it will cut asunder the pedal and pleural ganglion of the side to which the edge of the knife is directed, so that the separate connections of these ganglia with the cerebral ganglion is made evident. The pleural and pedal ganglia send nerves to the viscera and foot respectively. The pedal ganglia should be removed and examined in glycerine under the microscope; the otocysts lie embedded one in each ganglion. These structures are relatively much smaller than in the pond snails.

While examining the pedal nerves the student will notice a conspicuous tubular organ which lies embedded in the substance of the foot. This is a mucous gland which opens by a pore in the anterior end of the foot.

CHAPTER VI

ARTHROPODA—CRUSTACEA—ARACHNIDA

THE Arthropoda comprise the largest group in the animal kingdom. Animals such as insects, spiders, and prawns, which are covered outwardly with chitinous armour and possess jointed limbs, belong to this group.

The following peculiarities of structure are common to all Arthropods. The cells composing the skin secrete chitin and deposit it, so that it forms a uniform hard layer covering every outward part of the animal. The larger part of the alimentary canal is lined by a similar layer. Chitin is a lifeless material; it cannot grow, or stretch more than a little. Because of this it is necessary that the chitinous covering should be cast off from time to time to allow the animal to increase in size. After casting off its coat the animal grows rapidly, as the new chitin which is already formed beneath the old is soft and easily stretched. In many of the Crustacea lime salts are deposited in the shell and render it hard and brittle. All Arthropods are outwardly segmented; in this respect, and in the form of the nervous system, they resemble the Annelids. Between each segment the chitinous covering is thin and supple, and is folded

inwards. By this device, movement between the segments is permitted, though the soft inner parts are protected. In many Arthropods there are two thick chitinous plates on each segment—one on the dorsal surface called the Tergum, and the other on the ventral surface called the Sternum. Some or all of the segments are provided with elongated jointed outgrowths which are called appendages; these do different work, and are shaped in accordance with the requirements of that work: some are for walking, others for swimming, for catching prey, and for mastication. The pairs of appendages are arranged one on either side of the median line of the ventral surface. A segment never possesses more than one pair of appendages. Sometimes a detached portion of the body, which shows no outward sign of segmentation, bears several pairs of appendages; such a portion is considered to be an aggregate of several segments which have become united. Segments which are separate in the embyro often become fused together as the animal grows. The nervous system is essentially like that of an Annelid. The excretory and respiratory systems are different among the several groups. The vascular system is poorly developed; there is a heart situated above the alimentary canal close to the dorsal surface. The wall of the heart is pierced by openings called ostia, through which blood enters from a pericardial space. Blood leaves the heart by several arteries which open irregularly into the body space; the blood is therefore not wholly contained within

blood-vessels, but circulates freely between the various organs; it is ultimately collected into the pericardium and passes again into the heart. The principal groups of the Arthropods are the Crustacea, Insecta, Arachnida, and Myriapoda.

CRUSTACEA

Most of the Crustacea live in water, and obtain oxygen by means of gills. As regards their appendages, they differ from the other groups of the Arthropods. In every Crustacean there are two pairs of appendages, called the first and second antennae, which are placed on the head anterior to the mouth; as regards the other appendages, there is a considerable variety of form and arrangement. In a group of fresh-water Crustacea called the Branchiopods, most of the limbs are leaf like, and are useful both for swimming and for respiration, but the commonest type of appendage is the biramous type. A biramous appendage consists of a single basal portion, the protopodite, which bears an outer and an inner branch called respectively the exopodite and the endopodite. The two branches are often alike, and serve to beat the water in swimming, but the exopodite is reduced or absent in those legs which are used for walking, so that the leg becomes uniramous, like that of an insect. In nearly all Crustacea, except those which possess leaf-like limbs, the appendages are biramous at the time of their first appearance in

the embryo. In their vascular system the Crustacea are like other Arthropods. The large forms have a well-developed heart and arteries, the small forms have a poorly developed blood system; the heart may be long and tubular, as in the insects, or short and square. The excretory system consists of a pair of tubular glands situated in the anterior part of the body, which open on the bases of a pair of appendages close in front of or behind the mouth. The sexes are separate; the generative organs open on the bases of a pair of limbs, somewhere near the middle of the body. Most Crustacea possess a pair of compound eyes, which may be carried on stalks; many have also a single median eye when they are very young. As an example of the Crustacea we shall examine one of the most highly organized types —the common prawn.

THE FRESH-WATER PRAWN (*Palaemon*)

Large prawns are common in rivers and tanks in many parts of India. There are many kinds of them which differ from one another somewhat in their outward form, but not in their internal structure. They all possess five pairs of legs, of which the first two pairs end in pincers; the second pair of pincers is much the larger. On either side of the head, close behind the base of the large antennæ, are two sharp spines which are directed forwards, one behind the other. By these spines, and the character of the pincers, we can recognize a

Palaemon. Prawns belong to a large group of the Crustacea called the Decapoda, all of which possess ten legs and a pair of stalked compound eyes. Little is known of the habits of prawns in India; they seem to thrive well in foul, muddy water. One common kind, *P. carcinus*, may grow to over two feet in length, including the claws. The developing eggs may be found attached to the abdominal appendages of the mother.

External Appearance.—The body of a prawn consists of two parts—an anterior unjointed portion, the cephalothorax, and a posterior jointed abdomen which ends in a flapper-like tail. The stalked eyes protrude on either side from two semicircular notches in the front margin of the cephalothorax: they are freely movable; when turned forwards and depressed they fit into two cup-like depressions in the bases of the first antennae. A saw-like process called the rostrum projects forwards between the eyes. The cephalothorax consists of an aggregate of thirteen segments, five of which belong to the head, the remainder to the thorax. The division into head and thorax is inferred from the structure of other Crustacea; in the prawn there is no sign of a division between the head and the thorax. The abdomen consists of seven movable segments, six of which have a pair of appendages. The last segment, or telson, bears no appendages; it ends in a sharp point. The armour covering each of the first six segments of the abdomen is formed on the same plan. A single abdominal segment should be detached, and its skeleton examined. It is shaped like an

arch. The floor of the arch, which lies between the sockets of the appendages, is called the sternum; the arch itself is called the tergum. In each segment two plates called the pleura hang down from the tergum, one on either side; each pleuron overlaps the one of the segment behind it. Those of the 2nd segment are different from the others, for they overlap the segment next in front as well as the one behind. That part of the skeleton which lies between the limb sockets and the pleuron on either side is called the epimeron; it may seem hardly worthy of a special name, but in the thoracic region the united epimera form a high wall, or inner boundary, of the gill chamber, to which the gills are attached.

The Gill Chamber.—The gill chamber should now be examined. If the point of a pair of scissors be pushed under the posterior margin of the side of the thorax, it will enter the gill chamber. A groove, curving downwards in front, can be seen on either side of the thorax; a cut should be made with the scissors along this groove, and continued forwards along another horizontal groove, which lies close below the post-antennary spines. By this cut the gills and the bases of the appendages will be exposed, although the internal organs of the body will not be disturbed. The part of the armour which is detached by the cut is called the branchiostegite, or pleuron, of the thorax. The inner wall of the gill chamber is the epimeron of the thorax. The gills are for the most part attached to the epimeron. There are

eight pairs of gills which resemble one another in structure but not in size. We will describe the gills of one side. The hindermost gill is the largest; each gill is a little larger than the one in front of it. Just as each pair of appendages belongs to a segment, so does each pair of gills belong to a segment. Each segment from the 7th to the 13th has a pair of gills, one on either side; but the 8th segment has an extra pair. The last five gills are attached to the epimeron or inner wall of the gill chamber, above the bases of the five long legs; the attachment of the hindmost gill is higher than that of the others, and each gill is attached a little lower than the one behind it. The gill belonging to the 7th segment is attached to the base of the appendage of that segment. Of the two gills which belong to the 8th segment, one is fixed to the membrane which attaches the appendage of this segment to its socket, the other, which is very small, is attached to the rim of the socket. The small extra gill of the 8th segment is entirely hidden by its larger companion. One of the gills should be cut from its attachment and examined. It consists of a rod-like axis, to which are attached two rows of quadrangular plates arranged like the leaves of a book.

The Appendages.—The appendages of one side should now be removed and examined in succession, commencing with the first antenna. It has been mentioned that at the time of their appearance in the embryo the appendages of many Crustacea are biramous.

They consist at that time of a basal portion called the protopodite, which bears two branches, an inner endopodite, and an outer exopodite. This simple arrangement is still to be seen in the abdominal appendages of the adult prawn, but the appendages of the cephalothorax have lost their embryonic condition, and it is not always easy to understand which parts of the mature appendages have been formed out of any one of the three primary parts of the embryonic appendages. It is however known that each of the five pairs of thoracic legs have lost an exopodite in the process of development, whereas the first three pairs of thoracic appendages, which are called the maxillipeds, have retained their exopodites in the form of thin flexible processes.

The First Antenna.—This consists of a basal portion composed of four separate segments. The first is small, and ends in a spine on the outer side. The second is about three times as large as the first, and also ends in a spine on the outer side. The first two pieces are flattened and curved so as to form a cup-like hollow for the eye. The third and fourth are cylindrical and nearly equal in length. The third piece has a strong, blunt spine on its inner side; the fourth piece bears two flexible rods, or flagella. One of these is internal, that is to say, of the two it is nearer to the middle line, the other, which is external, bears a short third flagellum. The first antennae bear the otocysts, or auditory organs, which lie within their bases.

The Second Antenna consists of a globular basal

portion of two segments, which carries an outer and an inner limb. The outer limb is a flat leaf which is guarded in front by a spine, and projects horizontally outwards during life, to balance the animal in the water. The inner limb consists of a basal portion of four segments surmounted by a flagellum. Towards the inner side of the ventral aspect of the basal portion is the opening of the green gland, or kidney.

The Mandible consists of an elongated portion of great strength which is set obliquely in the side wall of the head; its lower end bears two teeth, one of which is placed just outside the aperture of the mouth, the other being situated within the oesophagus. At the base of the outer tooth is a short, three-jointed palp.

The mandibles lie on either side of the mouth; close behind them are two rounded lobes called the labia; these are not counted among the appendages.

The First Maxilla. This is the smallest of the appendages. It lies behind the labium and in contact with it, and possesses a double biting portion which projects inwards towards the mouth, and a short branch which is directed forwards.

The Second Maxilla.—The basal portion has two slender processes which project towards the mouth; there is another short branch which projects forwards. The most important part of this appendage is the leaf-like plate on the outer side which extends both in front of and behind the basal part. This is the scaphognathite; it is placed within the branchial chamber. When the

prawn is alive this plate is in constant motion, so as to renew the water in the gill chamber.

The Appendages of the Thorax.—There are eight pairs of these. The first three are called maxillipeds, the last five are the legs. The maxillipeds resemble one another in that each possesses a well-developed exopodite. The maxillipeds therefore differ from the five legs, which have lost their exopodites.

The First Maxilliped.—The basal portion is flat, and has a long, inner border, which is set with stiff hairs. The exopodite is a long, slender branch flattened and fringed with soft hairs. At its base, on the inner side, is a small process which may be called the endopodite. There are three leaf-like structures, or epipodites, on the outer side.

The Second Maxilliped consists of a basal portion which is soft and membranous as regards its posterior surface. A gill and an epipodite are attached to this membranous surface. The endopodite is composed of six segments; the last two are flattened and fringed with stiff hairs. The exopodite is exactly like that of the first Maxilliped.

The Third Maxilliped consists of a three- (or four-) jointed endopodite, which is long and resembles a leg, and an exopodite which is like those of the other maxillipeds. A gill is attached to the membrane which unites this appendage to the body.

The Legs.—In the embryo the legs are biramous, but the outer branch, or exopodites, are lost during development. Each leg contains seven segments, or podites,

which are named in sequence, commencing at the base, coxo-, basi-, ischio-, mero-, carpo-, pro-, dactylo-, podites. The first two legs are clawed, or chelate, the ends of their propodites and dactylopodite meet together like a finger and thumb. The second chela, or claw, is much larger than the first; in the female prawn it is much larger than in the male. The third, fourth, and fifth legs are not chelate. The generative duct of the female opens on the inner side of the coxopodite of the third leg. In the male the vas deferens opens similarly upon the fifth leg.

Abdominal Legs.—The first five pairs, which are called the swimmerets, are nearly alike. The sixth pair are different; they project laterally and form, together with the telson, the tail fin, by means of which the animal springs backwards through the water. The swimmerets each consists of a two-jointed basal portion, or protopodite, which bears a flattened, oar-like endopodite and a similar exopodite. In the case of the first, the endopodite is very small; in the second there are two additional short processes at the base of the endopodite; in the third, fourth, and fifth there is one such additional process which may be called a stylet.

INTERNAL ANATOMY.—The dorsal surface of the carapace must now be removed. Two parallel cuts should be made with scissors, commencing at the posterior margin of the thorax and passing forwards to end at the orbital margin, so that the rostrum is included between the cuts and removed along with the detached

portion, which represents the terga of the cephalothoracic segments. The terga of the abdominal segments should be similarly removed. It will now be seen that the lifeless carapace is lined internally with a living skin.

THE CIRCULATORY SYSTEM.—To see this properly it is necessary to inject the vessels. Injection can be performed with an ordinary hypodermic syringe containing insoluble carmine mixed with water. The heart is situated dorsally in the posterior part of the thorax, close below the skin which lines the carapace. When viewed from above it appears nearly triangular in shape, the apex of the triangle being directed forwards. Its shape cannot be properly seen until the pericardium, a thin membrane which encloses it on all sides, has been removed.

The Heart.—Examination of the heart should be postponed until after the arteries have been examined; it will however be described here. The heart, on being cut open, appears solid throughout, no definite cavity can be seen in it; the cut surface appears like a sponge, the interstices of which represent the cavity of the heart; in other words, the cavity of the heart is traversed in all directions by bundles of muscle fibres. This irregular cavity communicates with the pericardium through five pairs of openings called ostia, four of which can be seen from above. The fifth pair are on the ventral surface. The ostia are situated in the following manner: there are a pair situated close together on the upper surface near the middle line and not far from the

hinder border: these are easy to see. A second pair are placed further forwards, and widely apart, being close to the outer border of the heart. The third and fourth pairs of ostia are upon the posterior border; the third pair are not far from the middle line, and are therefore close behind the first pair. The fourth pair are placed below the outer angle of the heart where the lateral and posterior borders of the organ meet one another. The fifth pair are on the lower surface. The margins of the ostia are united to the pericardium by delicate strands, which hold them open. There must be some valves on the inner side of the ostia, for during the injection of the heart, the coloured fluid does not issue from these openings. The ostia are not always easy to see, especially in small prawns. They are well seen in specimens which have been kept for some days in strong spirit, for in this condition these apertures are usually found gaping open. In order to see the ostia to the best advantage, a heart which has been treated in this way should be split horizontally in two with a razor; the halves should be lightly stained, mounted in Canada balsam in the proper manner, and examined under the microscope. To see the arteries the heart must be injected; this is easily done by thrusting the needle of a hypodermic syringe, containing carmine and water, through the posterior wall into the middle of the heart. On slowly pressing the piston of the syringe, the heart will bulge and all the arteries become filled with the red fluid.

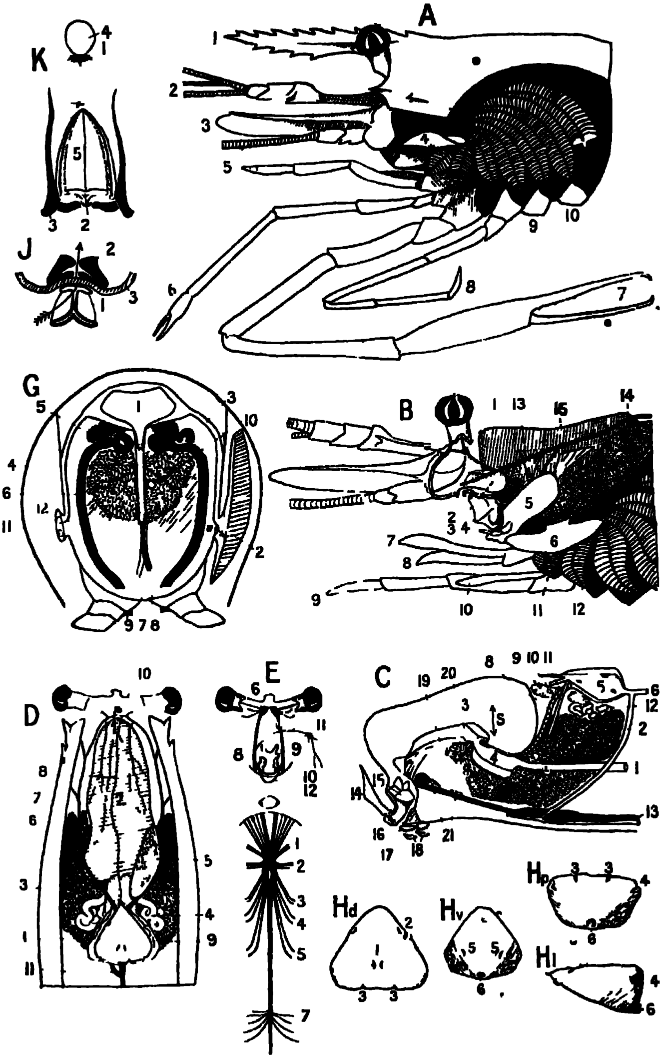
A
B
C
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PLATE IX.

THE FRESH-WATER PRAWN (*Palaemon sp.*).

A. The thorax after removal of the branchiostegite. 1. rostrum; 2. 1st antenna; 3. 2nd antenna; 4. the scaphognathite; 5. 3rd maxilliped; 6. 1st thoracic leg, or small chela; 7. large chela; 8. 3rd thoracic leg; 9 and 10. bases of the last legs.

B. Further dissection of thorax. 1. cerebral ganglion; 2. excretory pore; 3. renal gland; 4. labrum; 5. base of mandible; 6. scaphognathite; 7. exopodite of 1st mxped.; 8. exp. of 2nd mxped.; 9. endopodite of 3rd mxped.; 10. exp. of 3rd mxped.; 11 and 12. gills belonging to the 2nd and 3rd thoracic segments; 13. antennary artery crossing the mandibular tendon; 14. liver; 15. stomach.

C. Median longitudinal section through the thorax. 1. the intestine; 2. sternal artery; 3. cardiac stomach; 4. pyloric stomach; 5. heart; 6. dorsal abd. artery; 8 and 10. gastro-cardiac muscle; 9. testis; 11. hepatic artery; 12. vas deferens; 13. nerve-chord; 14. labrum; 15. inner mandibular tooth; 16. outer mdb. tooth; 17 and 18. biting ends of 1st and 2nd mxl.; 19. hastate plate; 20. guiding ridge; 21. endosternite. The arrow S indicates the direction of the section shown at Fig. J.

D. Thorax dissected from above. 1. heart; 2. stomach, 3. testes; 4. vas deferens; 5. mandibular muscle; 6. tendon of mdb. muscle, the muscle having been removed; 7. antennary artery; 8. ophthalmic artery; 9. pericardial artery; 10. gastric ganglion, 11. sternal artery.

E. The thoracic nervous system. 1 to 5. nerves to the five thoracic legs; 6. cerebral ganglion; 7. 1st abdl. ganglion; 8. circoes. comm.; 9. oesophagus, containing mdb. teeth, 10. postoes. nerve loop; 11. gastric ganglion; 12. endosternite

G. Diagrammatic transverse section at the posterior end of the thorax. 1 the heart; 2. gill; 3. efferent branchial artery; 4. sternal artery; 5. testes; 6. vas deferens; 7. posterior sternal artery; 8. thoracic nerve cord; 9. male generative aperture, upon the 5th leg; 10. intestine; 11. branchiostegite; 12. gill chamber.

H *d*, *v*, *p*, *l*. Dorsal, ventral, posterior, and lateral views of the heart from a specimen which has been hardened *in situ* in order to preserve the natural shape. 1. dorsal ostia; 2. antero-lateral ostia; 3 and 4. posterior ostia; 5. ventral ostia; 6. sternal artery.

J. Section through the pyloric stomach and floor of the cardiac stomach. 1. pyloric stomach; 2. posterior ends of the guiding ridges; 3. floor of cardiac stomach.

K. Structures seen in the floor of the cardiac stomach. 1. opening of the oesophagus; 2. position of the passage to pylorus; 3. the guiding ridges; 4. oval calcareous plate embedded in the front wall of stomach; 5. the hastate plate.

Arteries.—Five arteries leave the anterior end of the heart: a very small median ophthalmic artery, a pair of large antennary arteries, and a pair of hepatic arteries of medium size. One large artery leaves the posterior part of the heart; it arises not from the posterior border, but from the posterior part of the ventral surface. The ophthalmic artery is so small that in many cases it is not properly injected; it passes forwards in the middle line between two oval greenish bodies, which are the upper ends of the mandibular muscles, and comes to lie on the upper surface of the stomach; it passes forwards to the head, but does not supply the eyes in the prawn. The antennary arteries are much larger, and arise one on either side of the apex of the heart. Each gives off (1) a small branch to the pericardium, and passes forwards to the outer side of the mandibular muscle; it gives off (2) a gastric branch to the stomach, which reaches that organ by passing down the tendon of the mandibular muscle(3) A third branch of the antennary artery supplies a muscle which is contained in the base of the mandible, and a fourth branch is directed inwards to unite with its fellow of the opposite side, and with the ophthalmic artery upon the upper surface of the stomach. After giving out these four branches the antennary artery becomes directed towards the kidney and divides into terminal branches, which supply that organ and both the antennae. The hepatic arteries complete the group of five vessels which leave the anterior end of the heart. They issue from the ventral surface of the organ, close

to its apex, and plunge downwards together into the substance of the liver. While examining the hepatic arteries the student will observe a strand of tissue which passes from the apex of the pericardium to the dorsal wall of the pyloric chamber of the stomach. This strand lies upon the liver and between the hepatic arteries. If it be removed and examined microscopically it will be seen to consist of two bundles of striped muscle fibres separated by a minute artery; it may be called the gastro-cardiac muscle. One large artery leaves the posterior border of the ventral surface of the heart, and divides at once to form the dorsal abdominal and sternal arteries. The former takes a posterior course and comes to lie above the intestine; it supplies the muscles of the abdomen. The sternal artery, which is usually the widest blood-vessel in the body, takes a downward course towards the thoracic ganglionic mass; it lies in the median plane on one or other side of the intestine. Subsequently it will be seen, that the sternal artery perforates the thoracic ganglion, and divides beneath it into two branches which lie ventral to the nerve-chord; one branch passes to the head and is called the ventral thoracic artery, the other passes towards the tail and is called the ventral abdominal artery.

Alimentary System. The mouth is a large hole which lies between the mandibles; in front of it is a prominent quadrangular plate called the labrum. The mouth leads into a vertical oesophagus within which the inner tooth of each mandible is placed; the two teeth

oppose one another and form an efficient apparatus for grinding food. It is an interesting fact that there is no other means of grinding the food in the stomach of the prawn; in many other Crustacea, such as the crayfish, lobster, and crab, which do not possess an internal mandibular tooth, there is a well-developed grinding apparatus within the stomach. The oesophagus opens into the large stomach, which occupies about two-thirds of the length of the cephalothorax. The stomach of all the higher Crustacea is divided into two parts, which receive the same names as the two ends of the human stomach. The first part, into which the oesophagus opens, is called cardiac; the second, to which the intestine is attached, is called pyloric.

The Cardiac Stomach.—In the prawn the cardiac portion of the stomach is very large, while the pyloric portion is small, being scarcely more than a valve which regulates the passage of food into the intestine and prevents regurgitation. The cardiac portion of the stomach occupies nearly the whole of the cephalothorax in front of the heart. Upon its upper surface, the ophthalmic artery and branches from the antennary arteries, as well as the gastric nerves, may be seen. The stomach should be opened in its whole length and its contents washed out. The opening of the oesophagus and the inner mandibular teeth will now be seen in the floor of the stomach. A short distance behind the oesophageal opening there is a chitinous plate, which is embedded in the floor of the stomach; it is shaped like

the head of a spear, and may be called the hastate plate. On either side of this plate is a delicate rod, from which a row of fine hairs project inwards and overlap its margin. Posterior to the hastate plate is the opening of the pyloric part of the stomach: the passage is naturally closed, but it can easily be demonstrated with a blunt seeker. The hastate plate is enclosed between two elevated ridges, which are of a deep bluish-black colour. Judging from the fact that these ridges increase in height behind, and bend inwards over the pyloric opening, we may assume that they are useful to guide the contents of the stomach towards that opening; they may be called the guiding ridges.

The Liver.—The posterior half or more of the cardiac stomach lies embedded upon the liver. The liver is a large gland of the racemose type, that is to say, it is composed of a mass of short, branching tubules which are connected together like the twigs and branches of a tree. The liver is of a mottled red-yellow colour, and lies below and on either side of the posterior half of the cardiac stomach; it extends beneath the generative organs and heart, and is traversed by the intestine, which is attached to the posterior end of the pyloric chamber of the stomach.

The Pyloric Chamber.—The oesophagus must now be cut through, and the stomach raised from its natural position; the small pyloric chamber will then be found lying beneath the hinder part of the cardiac portion of the stomach. It is not always easy to see the attachments

of the intestine and of the hepatic ducts which open into the pyloric chamber. A few hours after death the viscera become so soft that the attachments of these tubes easily become broken. In order to examine the structure of the pyloric part of the stomach it should be cut across transversely. There is little or no cavity within it; the inner walls, which are in close contact with one another, are arranged so as to present in cross section an appearance somewhat like the letter H lying upon its side; in this position the letter will contain a single vertical line and an upper and a lower horizontal line, which all three together, represent the potential or closed cavity of the organ. That part of the cavity which is represented by the upper horizontal line is continuous posteriorly with the intestine, while that which is represented by the vertical line becomes similarly confluent with the two hepatic ducts, which therefore open into the posterior end of the pyloric chamber immediately below the opening of the intestine. The floor of the pyloric chamber is formed by a thick, chitinous plate, which is marked internally by a series of longitudinal grooves separated by low ridges. The intestine passes through the substance of the liver towards the abdomen, where it lies among the muscles and opens by the anus at the base of the telson.

The Abdominal Muscles.—The abdomen is almost wholly occupied by powerful muscles, which are of two systems. The one is called the flexor system, and is used to bend the abdomen so that the tail is brought

forwards beneath the thorax. The prawn uses the flexor muscles when it springs backwards through the water. The other muscular system is called extensor, for if the abdomen is in the bent position, it is made straight by the contraction of these muscles. The flexors, which are more powerful than the extensors, are ventral to the intestine, whereas the extensors lie dorsal to it. Both the flexor and extensor muscles of the abdomen are attached to the thorax anteriorly, the former to the sterna, the latter to the terga and epimera of the posterior thoracic segments.

THE NERVOUS SYSTEM.—The central nervous system is formed on the same plan as in the Annelids; that is to say, there is a pair of cerebral ganglia in front of the oesophagus, and a ventral gangliomated nerve-chord which lies along the whole length of the animal. The position of the ganglia is determined, as in a worm, by the segmentation, for there is one ganglion in each segment which supplies nerves to that segment. Just as the segments of the thorax are fused together, so are their ganglia fused to form a single ganglionic mass of considerable length. In this respect the thoracic nervous system of the prawn differs from that of many other Crustacea, in which each thoracic segment possesses its own special ganglion.

Cerebral Ganglia.—These are placed anterior to the stomach and below the level of its upper surface. Each gives off three large nerves, which enter the eye and the first and second antenna of the same side.

Circumoesophageal Connectives.—The cerebral ganglia are connected with the thoracic ganglionic mass by two large nerves, which lie one on either side of the oesophagus, and are called the circumoesophageal connectives. They are crossed by two bridges of tough, connective tissue, which lie between the oesophagus in front, and the thoracic ganglionic mass behind. These bridges may be called the endosterna; on either side they become resolved into muscular tissue. The circumoesophageal connectives give out some small nerves; the largest pair of these form a loop which embraces the oesophagus posteriorly. Small nerves are also given to the outer surface of the stomach. There is a small ganglion on the anterior wall of the stomach which is connected with the circumoesophageal chord on either side; from this ganglion a small nerve passes upwards on to the upper surface of the stomach, where it bifurcates and supplies the gastric wall.

The Thoracic Ganglionic Mass.—Posterior to the endosterna, the circumoesophageal chords become united in a long ganglionic mass, which is pierced by the sternal artery at a spot somewhat behind the middle of its length, and supplies nerves to all the appendages of the cephalothorax except the antennae. Many pairs of nerves arise from the ganglionic mass on either side. Some of these are directed anteriorly, others in the opposite direction; but one pair of nerves, the largest of all, are directed straight outwards; these enter the large chela, *i.e.* the second leg, or fifth thoracic appendage, and serve as a

guide among the confusion caused by the large number of nerves which spring from the mass. All the nerves, after leaving the ganglionic mass, divide into two branches, which enter the appendage to which they belong side by side. From the posterior end of the mass a stout chord, which appears outwardly to be single, passes towards the abdomen, where it enlarges into a ganglion, in each segment.

Excretory Organs.—These consist of a pair of renal glands, and the renal sac and its ducts. The renal glands lie one on either side of the head; they are nearly spherical, and measure one quarter of an inch in diameter, or more, in a large prawn. They lie almost wholly within the expanded basal segments of the second antennae, and are disclosed by the removal of certain muscles which surround them. The renal sac is easy to see, but a fresh specimen is required for its full demonstration. In order to see the sac, remove the carapace and skin of a large freshly killed prawn, being careful not to damage anything which lies beneath the skin. Between the upper surface of the stomach and the skin is a membranous tissue, which is like an empty bag lying along the whole length of the stomach. It should be grasped with forceps and gently raised from the stomach; it will then be seen that the posterior end of the sac is firmly attached to the generative organ, which is pulled forwards from under the heart. The renal sac must now be injected; this is easily done with a hypodermic syringe containing carmine and water. As a result of the injection, the

carmine flows at once fr m both of the external excretory apertures, which open upon the base of the second antennae. The whole renal sac and its ducts are now rendered visible. Two canals leave the ventral surface of the anterior end of the sac and take a downward course; they pass to the inner side of the circum-oesophageal connectives and bend outwards beneath them in the direction of the renal glands. The injection shows that the inner side and half of the upper surface of each kidney is covered with a sac, which receives the canal from the large renal sac, and gives forth another canal or duct which passes to the excretory aperture. The large renal sac has been compared to a coelom; the question as to whether the generative organ is developed from its wall is unsettled.

The Generative Organ.—This lies beneath the pericardium. In both sexes it is a tri-lobed greyish body, the ovary is somewhat larger than the testis. The generative ducts are a pair of translucent tubes which arise one on either side from the organ. The oviducts are short, and pass direct to their openings upon the bases of the third legs. The vasa defferentia, which are long and contorted, open similarly upon the 5th legs. Some of the contents of the vasa should be examined under the microscope. The spermatozoa are round nucleated cells, which are provided with numerous stiff, radiating processes; they are incapable of active movement.

Sense Organs.—The sense organs of the prawn are

the eyes and the otocysts. The eyes are of a peculiar structure, being composed of a large number of separate columnar elements, which lie side by side and are called ommatidia; the eyes are therefore said to be compound. Many of the higher Crustacea, and nearly all the insects, have eyes of this kind. The compound eyes of the prawn and of some other Crustacea are globes borne upon movable stalks. The outer surface of the globe is black, and exhibits, on close inspection, an hexagonal pattern like the surface of a honeycomb. The internal structure of the eye can only be studied in stained sections, which have been cut with the microtome. As all the ommatidia are alike in structure, it will only be necessary to describe one of them.

The Structure of an Ommatidium.—The outer layer is called the cornea; it is chitinous and transparent during life. In many Arthropods it is shaped like a biconvex lens. Beneath it is the corneagen, a layer of cells which forms a new cornea beneath the old one, before the latter is cast off in moulting. The cornea of adjacent ommatidia form a continuous sheet, which is the outer covering of the globe of the eye. Beneath the corneagen is the crystalline cone, a homogeneous body which is transparent during life. The cone is enclosed within certain large cells, which become deeply stained and are generally much vacuolated, as a result of the treatment they undergo in the process of section-cutting. The inner ends of the cone cells are long and pointed. Beneath the cone lies the rhabdom, a rod-like body which

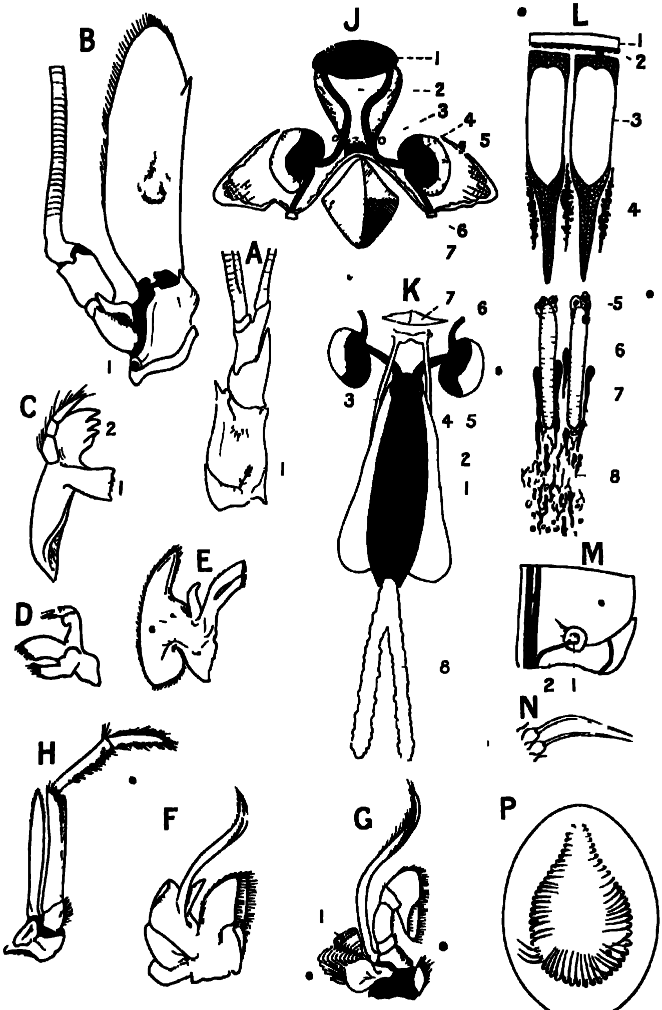
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PLATE

PARTS OF THE PRAWN (*Palaemon carcinus*)

A First antenna 1 otocyst

B Second antenna 1 excretory pore

C Mandible 1 inner tooth 2 outer tooth

D First maxilla

E Second maxilla

F, G, and H 1st, 2nd and 3rd maxillipeds

J View of the anterior end of the stomach and the renal sac 1 renal sac, 2 stomach 3 circumoral commissures, 4 lesser renal sac 5 renal gland 6 excretory pore 7 labrum

K Renal sac viewed from above, to show its posterior connection with the generative organ, 8

L Longitudinal section through the compound eye 1 cornea 2 corneagen 3 crystalline cone, 4 outer pigment cell 5 retinula cell, 6 rhabdom, 7 inner pigment cell 8 internal limiting membrane.

M Base of 1st antenna laid open 1 otocyst 2 nerve to otocyst × 2

N Sensory hairs from the otocyst × 100

P The otocyst × 20

is also homogeneous; it has however a striated appearance, due to certain fibres which are embedded in it. The rhabdom is regarded as the perceptive part of the ommatidium. The term retinula cell is given to certain cells which secrete the rhabdom; their nuclei can be seen at the outer end of the rhabdom. The inner end of the rhabdom is directed towards a large spherical mass of tissue which is composed of nerve-cells and fibres, and occupies the centre of the globe of the eye. This mass is the optic ganglion. The inner ends of all the rhabdoms are separated from the ganglion by a thin limiting membrane. The means of connection between the rhabdom and the optic ganglion seems to be a matter of doubt. Some authors say that the inner ends of the rhabdoms themselves are prolonged as filaments into the ganglion; others say that the inner ends of the retinula cells are prolonged in this manner. The several ommatidia are separated from one another by cells which are full of black pigment. There are two series of such cells—an outer series which lies among the cones, and an inner series which separates the rhabdoms. In Palaemon, the inner series is continued past the limiting membrane into the ganglion. The pigment cells are known to be very amoeboid, and to take up different positions according as the light which is falling on the eye is bright or dull; their function is to prevent light passing between the elements.

Otocysts.—These are often spoken of as auditory organs, but it is probable that their function is to give

a sense of position and balance; in other words, they are comparable not to the internal ear, but to the semicircular canals of a vertebrate animal. The otocysts lie within the basal part of the first antennae, one on either side. In order to examine them, remove a first antenna and split open the basal part of it by cutting along either side with fine scissors. The otocyst will be seen as a spherical pouch, which is attached to the upper of the two walls of the appendage. The aperture of the pouch is upon the upper or concave surface of the antenna; but it is scarcely visible, since it lies in the crevice between the first and second parts of the appendage. In the centre of the sac is a depression, and a small nerve may be seen passing from the main nerve of the antenna to this depression. Having exposed and examined the sac from the inner side, it should be cut off, placed in a drop of water on a slide, and examined with the microscope. It is full of fine sand, which must be loosened with a needle and washed out; when this has been done the otocyst should be covered with a slip and examined more carefully. A large number of long delicately pointed hairs will be seen; these are not scattered irregularly, but are arranged in a linear series which forms an oval. Each hair is distended immediately above its base or point of attachment, through which it receives a nerve fibre. In the natural condition these sensory hairs lie among the sand grains. It is difficult to understand how the sand gets into the otocyst.

ARACHNIDA

The group of the Arachnida includes the scorpions, spiders, mites, and ticks, animals of small size which breathe air; it also includes Limulus, the king crab, a larger animal which lives in water and takes in oxygen by means of gills. The anterior part of the body, or cephalothorax, of every Arachnid contains six segments, each of which possesses a pair of appendages. The part of the body which is posterior to the cephalothorax is called the abdomen. In the embryos of many Arachnids the segments of the abdomen bear appendages, but it is only in the aquatic Limulus that they persist throughout life. In spiders and in Limulus the abdomen is separated from the cephalothorax by a constriction, but the abdomen of scorpions, mites, and ticks is broadly fused with the cephalothorax. The presence of six pairs of appendages is the most noticeable characteristic of the Arachnids. The first pair of the appendages is placed in front of the mouth; but they are quite unlike the antennae of the insects and Crustacea; they are called chelicerae. The second pair usually lie one on either side of the mouth; they are called pedipalpi. The four posterior pairs are in most cases used for walking. The respiratory system differs among the several orders in an interesting manner. Limulus breathes by means of thin leaves, or lamellae, which, being attached to the abdominal legs, are in contact with the water. The

scorpions and spiders breathe by means of special organs called lung books, which contain a number of lamellae resembling the leaves of a book. Lung books open on the abdomen, and when multiple are arranged segmentally in pairs. It is one of the most interesting facts in embryology that the lamellae of the lung books are first formed upon short appendages, which protrude from the abdominal segments. As development proceeds these appendages diminish in size, and their lamellae are received into pockets which appear at the base of the diminishing appendages. The pockets and the lamellae persist throughout life as the lung books. The mites and ticks, and certain other Arachnids, breathe like insects by means of trachea, which develop in the embryo as outgrowths from preformed lung books and ramify through the body. Arachnids mostly live by sucking the nutritive juices of other animals. The alimentary canal is usually a straight and narrow tube, provided with a bulky liver. The nervous system and circulatory system are of the Arthropod type. The sexes are separate; the ducts of the generative organs open on the first segment of the abdomen. Two kinds of excretory organs are found in the Arachnids: Malpighian tubes occur as in insects, but certain organs called coxal glands, which somewhat resemble the excretory glands of the prawn, are also found.

THE SCORPION (*Buthus*)

Scorpions are fairly common throughout India. There are many kinds of them, but all are essentially alike in structure. They are found in houses, especially in dusty, narrow places which are seldom disturbed. They are often found beneath old matting. Scorpions are sometimes found in congregations of a hundred or more among deserted lumber. Seventeen of such a congregation were dissected, and all were found to be females, mostly in a pregnant condition. The habits of scorpions are not well known; they are viviparous, and give birth to about thirty young in a single night. The young ones resemble their parents. At first they are white, and remain clinging to the back of their mother. After about a week they moult and become brown; they then leave the mother and lead an active independent life. Scorpions are also found beneath stones in hilly places; a very large kind, over six inches in length, is not uncommon in many parts of India. The kind which is usually found in houses in Bengal grows to about three inches in length.

External Appearance.—The body of a scorpion consists of a cephalothorax which bears six pairs of appendages, an abdomen containing seven segments, and a six-jointed tail. The upper surface of the cephalothorax is formed by a single plate, which carries two sets of simple eyes. There are a pair of large eyes close to the

middle line near the centre of the plate, and a group of smaller ones on either side, very close to the front margin. The segmented character of the cephalothorax is indicated by the presence of the six pairs of appendages. Each of the seven segments of the abdomen is provided with a separate dorsal plate, or tergum; these plates increase in length from the first to the seventh; the last one is nearly triangular in shape. The ventral surfaces of the abdominal segments are not all alike. The first one bears a rounded plate which covers the opening of the generative ducts, and is called the genital operculum. The 2nd abdominal segment bears a pair of remarkable comb-like appendages called the pectines; their function is unknown, they are supposed to be of some use when the sexes meet. From the 3rd to the 6th abdominal segments the sterna are perforated on either side by the openings of the lung books. The sternum of the 7th segment resembles the tergum of the same segment. The tail, which is attached to the 7th abdominal segment, consists of six separate segments, which are enclosed on all sides by chitin; the last one bears the acutely pointed sting. Within this segment are a pair of poison glands, the ducts of which open below the point of the sting. During life the tail is bent forward over the abdomen with the sting directed forwards. In combat the sting is usually thrust forwards over the head, but it may be directed to either side. It seems to be doubtful as to whether the larger scorpions can by their sting cause the death of a man, or even a child.

The Appendages.—The first two pairs of appendages, the chelicerae and pedipalpi, should be considered in their relation to the mouth. It is not until the small chelicherae have been lifted up, and the bases of the larger pedipalpi separated from one another, that the facial or oral respect of the animal is disclosed. The chief feature of this aspect is a prominent hairy ridge called the labrum, which is placed vertically in the middle line. The mouth is a minute round hole situated below the lower end of the labrum; it is at the bottom of a deep recess, and cannot be properly seen without dissection.

The chelicerae are the small appendages which overhang the labrum; each consists of three portions, a basal piece and two others, which combine to form a small pincer. The shape of the chelicerae differs widely among the various kinds of scorpions. The pedipalpi are the large pincers; they contain seven pieces separated by as many joints. The inner edge of the first, or basal, portion is provided with a bluntly dentate margin. We may assume from its position that this margin is useful for grasping when the scorpion feeds. Scorpions in captivity will feed upon cockroaches; in order to feed they tear a large hole in the side of the abdomen of the insect and push their head into it; the mouth of a scorpion is so small that it can only admit juices and pulp. The last two pieces of the pedipalpi are opposed to one another like a finger and thumb, and form the large pincer which is used to catch and hold prey. The large pincer also varies considerably among the different

species; in Buthus it is slender, but in the large rock scorpion the last segment but one is broad, and contains much muscle, so that the pincer is very powerful. The other four pairs of appendages are the walking legs: they are closely alike: each has seven joints. From the basal portions of the first two pairs of walking legs a bluntly pointed projection is directed forwards; the four conical points thus formed are to be seen lying side by side below and in front of the mouth. They are movable, and are doubtless useful in feeding.

INTERNAL ANATOMY.—The animal should be killed with chloroform, and pinned down upon its ventral surface beneath water. Two cuts should be made through the skin, one along either side close to the outer margins of the terga and the cephalic shield. These cuts, which must be made with fine scissors, should commence at the posterior border of the 7th abdominal segment. In a pregnant female, the internal organs are tightly compressed, and will protrude when the first cut is made. Commencing at the 7th abdominal segment, the terga must be removed; to do this they must be lifted up from behind, and everything which is attached to their inner surface should be detached by cutting. In performing this operation, it will be noticed that there is a pair of muscular bands in each segment, placed vertically, one on either side, and close to the middle line. These are the dorsiventral muscles; the heart is placed in the middle line between them.

The Circulatory System.—Because of its position, the

heart must be examined first. It is a tubular organ of a faint greenish colour which occupies the middle line. It is surrounded by a close-fitting sheath, the pericardium, which was in contact above with the inner side of the terga. The terga having been removed, we see the heart, covered by its pericardium, lying in a deep groove upon the upper surface of the liver.

The structure of the heart is more easily seen in specimens which have been preserved for a time in spirit; in this condition the organ is shrunken, the segmentation is made evident, and the ostia gape. The heart must be removed in the pericardium and examined under the microscope. In order to remove it, raise the posterior end with forceps, and cut the fine threads which hold it down; at the same time observe how these threads are disposed: the most conspicuous of them are a pair of arteries which are given off from the heart in each segment in a ventral direction. Close to each artery is a small band of muscle fibres, which are attached not to the heart itself but to its pericardial sheath, These ventral pericardial muscles, as well as certain dorsal pericardial muscles which connect the dorsal surface of the pericardium with the inner side of the terga, must, when they contract, expand the pericardium and draw blood into it. The heart is a cylindrical tube composed of a single layer of large fibres, which are placed side by side and completely surround it; these fibres end abruptly on either side of the mid-ventral line of the organ. There are a pair of ostia in each segment.

Each ostium is a large elongated aperture, which occupies at least a quarter of the whole circumference of the heart; the upper ends of each pair are nearly in contact in the mid-dorsal line. The margins of the ostia are turned inwards and project into the cavity of the heart, so as to form valves which must prevent blood leaving the heart through these apertures. The valves of each pair of ostia are united in the middle line and together form septa, which partially divide the tubular cavity of the heart into a number of chambers. There is one such chamber in each segment of the abdomen.

The scorpion is a good type in which to study the tubular heart of an Arthropod, but the remainder of the blood system can be dissected only with great difficulty in small scorpions, therefore it will be briefly referred to here. The anterior end of the heart is prolonged into an artery which descends somewhat so that it comes to lie upon the upper surface of the alimentary canal; behind the brain this artery expands into a chamber from which most of the important arteries of the body issue. Among these may be mentioned arteries to each of the limbs, an artery which lies on the dorsal surface of the alimentary canal, and a pair of arteries which embrace the oesophagus and unite below it to form a single vessel, which passes to the posterior end of the body in close companionship with the ventral nerve-chord. A remarkable feature of the arterial system is the close relationship of many of the large arteries with the nerves.

Alimentary System.— The alimentary canal is a straight tube which is smaller in diameter and less conspicuous than the heart. It is separated from the heart by the liver substance, for the right and left halves of that organ are more or less united in the median plane both above and below the alimentary canal. In order to see the canal the liver must be gently separated in the middle line; when found it should be traced up to the point where it passes beneath the cerebral ganglia. The small mouth opens into a pharynx, which is lined by chitin and functions as a suction-pump; this opens into a very narrow oesophagus, which lies beneath the cerebral ganglia. Posterior to the ganglia the oesophagus dilates slightly to form a small crop, which receives at its posterior end the openings of the salivary glands. The crop opens into the narrow intestine, which receives four pairs of ducts from the liver. In the 7th abdominal segment the intestine receives a pair of malpighian tubes. These adhere to the dorsal surface of the intestine; to see them clearly the portion of the intestine to which they are attached should be removed and examined under the microscope. The intestine enters the tail and opens on the ventral surface between the last two segments.

The glands which open into the alimentary canal are the salivary glands and the liver. The salivary glands lie in the cephalothorax on either side of the canal. These organs somewhat resemble the liver in appearance, but they are much more coarsely lobulated; their ducts

join the alimentary canal just behind the crop. The liver is a very large brown organ; it occupies nearly the whole of the abdomen, and sometimes the first segment or two of the tail.* It is a racemose gland consisting of a mass of small tubules, which are in communication with the hepatic ducts in the same way as the twigs of a tree are in communication with the main stem. Because of its size we may guess that it performs other important functions besides secreting the digestive juice.

The Generative Organs.—Female scorpions seem to be much more common than males, in certain circumstances. The ovaries of a female scorpion consist of two long tubes, which lie in the abdomen beneath and among the liver; they open together in the middle line upon the ventral surface of the 1st abdominal segment. At the posterior end of the abdomen the two tubes are continuous, and they are united in their length by three or four communicating tubes, which cross the middle line of the body. Numerous large round ova, which are easily visible to the naked eye, project from these ovarian tubes; in this position they are fertilized and give rise to fully developed embryos. Thirty or more young ones are born at one time. The testes in the male are also tubular organs opening upon the first abdominal segment. There are also two pairs of tubular pouches which function as seminal vesicles.

Excretory System.—We have already seen that there are a single pair of malpighian tubes, as in insects; it is remarkable that scorpions can perform their functions

by means of a single pair of tubes, while an insect of equal size, such as a cockroach, requires many more. There is also a pair of large organs on either side of the cephalothorax, close in front of the endosternite, which are called the coxal glands. In structure these organs are tubular glands, very like the green glands of a prawn, but relatively larger. In the adult scorpion, however, these organs do not open to the exterior, so that it is difficult to understand how they can function as excretory organs. In young scorpions they open upon the bases of a pair of legs.

Endosternite.—This structure used to be called the diaphragm of the scorpion. The student will learn that the diaphragm of a mammal is a sheet of tough, fibrous and muscular material, which separates the cavity of the thorax from that of the abdomen, and is pierced by several tubular organs which pass from one cavity to the other. In many ways the endosternite of a scorpion is like a diaphragm. It is composed of condensed connective tissue fibres, and lies obliquely between the cephalothorax and abdomen, so that its thoracic face may be called either dorsal or anterior, and its abdominal face ventral or posterior. The endosternite is shaped somewhat like a bird with outstretched wings. It bears several pairs of projections, which give attachment to muscle fibres. It is pierced by the alimentary canal and the nerve-chord, and by the blood-vessels which accompany these structures. In order to remove the endosternite, open a scorpion and leave it in water until it

begins to rot, when the organ can easily be pulled out, its muscle attachments brushed off, and the apertures examined. If the scorpion be soaked in caustic potash, the endosternite will be dissolved, together with the soft organs. This fact shows that the endosternite is different from other chitinous structures within the cephalothorax, which are not dissolved by caustic potash. The chitinous structures to which I refer, are formed as ingrowths from the skin in connection with the various appendages, and give attachment to muscles.

Nervous System.—The cerebral ganglia can be seen at an early stage of the dissection; when the carapace is raised, the median eyes become detached from the transparent, chitinous cornea which covers them. The eyes can then be seen as conspicuous black bodies which are connected with the cerebral ganglia by means of two stout nerves. The optic nerves are conspicuous, and indicate the position of the cerebral ganglia, which lie in contact with one another upon the upper surface of the oesophagus. The cerebral ganglia also give off smaller nerves to the marginal eyes, and are connected with the suboesophageal ganglionic mass by means of two short, stout connectives, which embrace the oesophagus. These are easily broken; when the carapace is raised the optic nerves pull on the cerebral ganglia so as to break the connectives. Below the alimentary canal is a large ganglionic mass which occupies much of the floor of the cephalothorax; this gives off a number of nerves, one to each of the six pairs of appendages. From its posterior

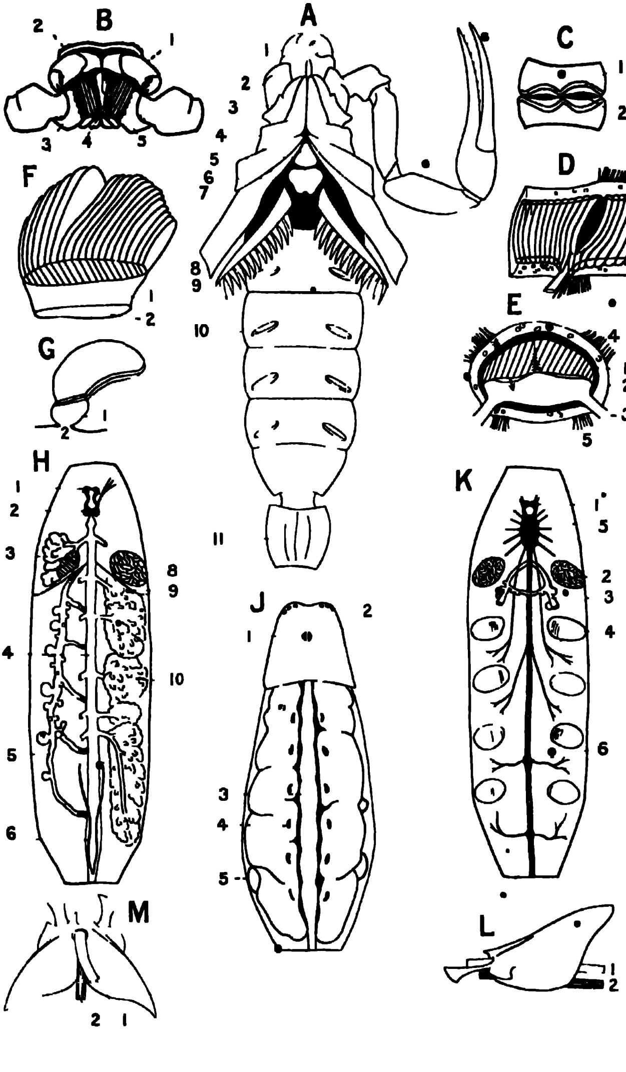
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PLATE XI.

THE SCORPION (*Buthus sp*).

A. Ventral aspect of thorax. 1. chelicera; 2. base of pedipalpus; 3, 4, 7, and 8. bases of the four walking legs; 5. the sternum; 6. genital operculum; 9. pecten; 10. opening of lung book; 11 1st caudal segment. (There should be a larger number of teeth on the pecten.)

B. Oral aspect. 1. chelicera; 2. lateral eyes; 3. serrated base of pedipalpus, used for mastication; 4. mouth; 5. labrum.

C. Dorsal wall of the heart, cut out to show a pair of ostia and their surrounding valves viewed from the inside. 1. margin of valve; 2. ostium.

D. Heart and pericardium viewed from the side, showing one ostium.

E. Diagrammatic section through heart and pericardium close to a pair of ostia. 1. wall of heart; 2. wall of pericardium, 3. ventral artery; 4 and 5 dorsal and ventral pericardial muscles. The arrow indicates one of the ostia.

F. A lung book. 1. the air chamber; 2. the external aperture.

G. The lung book in section.

H. The digestive organs, etc. 1. median eye, 2. cerebral ganglia; 3 salivary glands; 4. the intestine; 5. the ovary; 6. malpighian tubes; 7. nerves to lateral eyes, 8. coxal gland; 9. endosternite; 10. liver.

J. Organs exposed after removal of the abdominal carapace. 1. median eyes; 2. lateral eyes; 3. heart lying within pericardium; 4. dorsiventral muscles, piercing the liver; 5. a developing embryo.

K. The nervous system, etc. 1. cerebral ganglion; 2. coxal gland; 3. the oviduct; 4. lung book; 5. thoracic ganglionic mass; 6. 2nd abd. ganglion.

L. Endosternite removed and viewed from the side. 1. intestine; 2. nerve-chord.

M. Endosternite from above.

end the ventral nerve-chord is given off, and passes into the abdomen, accompanied by a pair of nerves, which lie for a short distance one on either side of the nerve-chord, but end in the region of the first lung book. In the abdomen the nerve-chord is double, and is provided with three pairs of ganglia, which distribute nerves as shown in the diagram; the nerve-chord is continued into the tail, in every segment of which is a ganglion.

The Respiratory Organs.—These consist of four pairs of lung books which open upon the abdominal sterna. To examine them properly, one of the abdominal segments should be cut out and soaked in caustic potash; this may be done when the dissection of the other organs is completed. By this treatment everything but chitin will be dissolved, and the true form of the organs, which are wholly composed of chitin, will be seen. A lung book consists of two parts—a ventral part or air chamber, which opens to the outside, and a dorsal part, which resembles the leaves of a book. The respiratory leaves are attached below to the roof of the chamber; otherwise they are quite free, although they touch one another like the leaves of a book. In the roof of the air chamber are a number of linear apertures set parallel with one another; air passes through these apertures into the respiratory leaves, for each leaf consists of two thin layers of chitin united at their edges. In order to understand how respiration is carried on, the student must remember that blood lies between the leaves and air lies within them, between their component layers. The leaves do

not project into the air chamber but into the cavity of the abdomen, like the leaves of a book which is lying upon its back. They lie within a sinus, or blood space, which is surrounded by a delicate membrane. The membrane hides the respiratory leaves from view, until it is dissolved by the caustic potash.

CHAPTER VII

INSECTA

The Insects form the largest group of the animal kingdom; it has been estimated that over a quarter of a million of different species have been described, but there must be many more than this in the world. Besides being the largest, they are one of the most definite groups; there is never a doubt as to whether an animal is an insect or not. The body of an insect is clearly separated into three regions—the head, thorax, and abdomen. The head bears four pairs of appendages, a pair of antennae and of mandibles, and two pairs of maxillae. The thorax is composed of three segments, named the pro-, meso-, and metathorax, each of which bears a pair of walking legs. In many insects the meso- and metathorax each bear a pair of wings. The abdomen contains from five to ten segments, which are devoid of appendages. The method of respiration is peculiar to the class. Some of the Arachnids however, share the peculiarity. Air is carried to all parts of the body by a system of tubes or tracheae, which open to the outer world in a row of laterally placed apertures called the stigmata. The tracheal tubes are kept open by a spiral

thickening of the inner wall; they ramify through all parts of the body, their minute terminal twigs can be seen with the help of the microscope lying between the individual cells of the body, that is to say, they are in the same relation to the tissues as the blood capillaries of other animals; accordingly, we find that the vascular system is poorly developed in Insects. This distribution of air throughout the body lessens the specific gravity of the whole, an important fact to a flying animal. The vascular system is poorly developed; there is a tubular heart placed dorsally. The excretory system consists of a large number of delicate tubular outgrowths from the gut which are called malpighian tubes.

The nervous system is of the typical Arthropod type, but the cerebral ganglia are much larger than in other Arthropods. The sexes are separate, the generative organs open at the posterior end of the abdomen. Parthenogenetic development occurs in some insects, that is to say, eggs may develop for many generations without being fertilized by a male cell; this phenomenon occurs in the bees and aphides. There are many orders of Insects. We shall examine the cockroach, which is one of the Orthoptera.

THE COCKROACH (*Periplaneta australis*)

Cockroaches are common throughout India, and can generally be found where food is stored. After leaving the egg they cast off their skin or moult from time to

time as they grow. The wings do not appear until the last moulting. In a European species of cockroach the males are wingless.

EXTERNAL STRUCTURE.—The head is attached to the thorax by a soft neck, and is therefore distinct and freely movable. It is expanded laterally, but compressed from before backwards. It is somewhat like a wedge with the apex downwards. On either side of the head are the compound eyes, which are black and glossy. Examine them with a lens in order to see the component elements. On either side in front of the eyes is a large oval space filled with soft skin to which the antennae are attached; close to the upper and inner margin of this space is a circular white spot called the fenestra. The anterior surface of the head is known as the clypeus; it is broad above, but becomes suddenly narrow below, and gives attachment by means of a hinge to a leaf-like plate called the labrum, which lies in front of the mouth. The top of the head is called the epicranium; the sides of the head, both behind and below the eye, are called the genae. Much of the sides of the head below the level of the eyes is occupied by the mandibles.

Appendages of the Head.—As in all insects, there are four of these: one pair of antennae, a pair of mandibles, and two pairs of maxillae. The antennae are slender tapering rods, containing many joints. The mandibles are flattened pieces of chitin; each is limited by an outer smooth curved border, which can be seen below the genae and behind the clypeus, and an inner border

which bears a row of six or seven triangular teeth. The inner borders of the mandibles meet one another below the mouth, so that the teeth interlock. The mandibles appear as though fastened to the genae, but their real points of articulation are in front of and behind the line which separates the mandibles from the genae.

First Maxillae.—The first maxillae, which are situated just behind the mandibles, are rendered conspicuous by their long palps. Each contains a basal portion composed of two segments, the cardo and stipes. The cardo is fixed to the head, and the stipes is attached to the cardo, at right angles to it. The stipes bears three things, externally a long five-jointed palp, and internally the lacinia and galea, which are closely associated with one another; the lacinia is shorter than the galea, and is set with a row of stiff hairs along its inner border.

Second Maxillae (Labium).—As in all insects, the second maxillae are united in the middle line to form a single, plate-like structure known as the labium. The right and left halves of the labium, considered separately, bear a strong resemblance to the first maxillae. The broad basal portion consists of two pieces, mentum and submentum, both of which are attached to the head below the insertion of the neck. In spite of its name, the submentum is above the mentum. The mentum gives attachment to a pair of three-jointed palps, between which lies a bilobed process called the ligula; each lobe of the ligula terminates in two pieces, which are sometimes called glossa and paraglossa.

The Thorax.—The thorax contains three segments, called the pro-, meso-, and metathorax, each of which is protected by a dorsal, a ventral, and lateral plates. The dorsal plate or pronotum of the prothorax is much larger than those of the other two segments from which the wings arise. On either side of each segment is a pair of narrow curved plates which are in close contact with one another; to the posterior member of each pair the walking leg of the segment is attached, and the lower end of the anterior plate is fastened to the sternum of the same segment. The sternal plates are narrow and inconspicuous. Each thoracic leg contains ten segments. Counting them from the base of the limb, the first is called the coxa, the others in succession are named trochanter, femur, tibia, and tarsus. The name tarsus is applied to the six small segments which terminate the limb. The last segment of all is called the pulvillus; it bears a pair of claws. There are two large tracheal openings, or stigmata, on either side of the thorax.

The Abdomen.—The abdomen contains ten segments, the first seven of which are obvious. The segments are protected above and below by tergal and sternal plates, which are in contact with one another on either side. Posterior to the 7th segment are the small 8th and 9th segments, which are placed as though they have been pushed forwards beneath the 7th segment. The 10th segment forms a terminal plate, like the telson of a prawn; it is flattened horizontally, and is divided

into two wings by a deep median notch; on either side of its base are two jointed tapering rods, the cerci. The 1st segment has no sternum. The sterna of the last three segments differ in the two sexes. In the male the sternum of the 9th segment bears a pair of styles, in the female the seventh sternum is much enlarged, and looks like the forepart of a boat; it encloses a cavity called the genital pouch. Beneath the antero lateral angles of each of the first seven abdominal terga is a respiratory opening, or stigma.

Circulatory System.—The heart of a cockroach is a segmented tube which lies close beneath the terga in the middle line of the abdomen and thorax. The heart should be examined in the living insect before it is killed for dissection. With the help of a lens, the contraction of the heart can easily be watched through the transparent terga. The rhythm is so fast that it is difficult to count. The heart is provided with ostia, and is much like that of the scorpion; but it is smaller, and more difficult to investigate. A good method is to remove the organ subsequently by cutting out the median strip of the terga to which it is adherent; it can then be examined microscopically from the inner side; it may be lightly stained and mounted in Canada balsam.

INTERNAL ANATOMY.—Cut off the wings and legs, and pin out the body beneath water; remove the terga of all the segments by cutting with scissors along either side. The heart, being adherent to the terga, will be

removed along with them. The body appears filled with a flocculent white material called the fat body, among which lie the digestive organs. The alimentary canal must be gently separated from the fat body. It is fastened to the sides of the abdominal cavity by several glistening white threads, which must be cut. These threads are the tracheae, which carry air from the stigmata to the walls of the alimentary canal.

The Alimentary Canal.—This consists of a crop, gizzard, mid gut, and hind-gut, and is provided with three sets of glands—salivary, digestive, and excretory. The best way to see the first part of the alimentary canal, which lies within the head, is to split the head of a second specimen exactly in the middle line with a razor. On examining the cut surface, the oesophagus will be seen as a brown curved tube, surrounded by white, fatty material. The oral aperture is guarded in front by the narrow part of the clypeus, on either side by the base of the mandibles, and behind by the base of the lingua. The lingua is a median chitinous process, about two millimetres in length, placed between the mouth and the labium. The duct of the salivary gland opens at the base of the lingua on its posterior aspect. If the lingua be torn off, part of the salivary duct comes away with it. The salivary duct is lined with a spiral thickening, and has a remarkable resemblance to a trachea.

The examination of the intestines may now be carried on in the dissection from above. The student must first observe that there are two encircling clusters

of tubes attached to the alimentary canal; the anterior of these consists of eight short, stout tubes, or coeca, which secrete a digestive ferment; the posterior cluster contains twenty to thirty long, slender yellow tubules, which are called malpighian and are believed to have an excretory function. That part of the canal which lies between these clusters of tubes is the mid-gut, and is developed in the embryo from endoderm; that part of the canal which lies in front of the digestive tube, and that which lies behind the excretory tubules, including these tubules themselves, are ectodermal in origin. The first and last ectodermal portions of the canal are called the stomodeum and proctodeum respectively. The stomodeum consists firstly of the oesophagus, which lies in the head; secondly, of a long, thin-walled sac called the crop, which occupies the thorax and part of the abdomen; and thirdly, of the gizzard, a small spherical body which contains eight large chitinous teeth. The gizzard opens into the mid-gut; the passage between the two is guarded by a funnel-like valve. The mid-gut is comparatively short: it joins the proctodeum, in which three portions are recognized a short, narrow ileum, a long white colon, and a short expanded rectum; the anal opening is beneath the 10th segment, and is guarded on either side by a pair of podicle plates. The inner wall of the rectum is raised into six ridges, which project into and nearly block up the tube; they are called rectal glands.

The Salivary Glands.—These lie on either side of the crop in its anterior half. The glands of the right and left side are quite separate from one another; moreover, the gland of either side consists of two portions, an upper and lower, between which is placed an elongated sac, the salivary receptacle. The receptacles and the glands of either side have each their own duct, which first meet their fellows of the opposite side before becoming united in a single duct. The salivary duct enters the head beneath the nerve-chord, and opens at the base of the lingua.

The student should remove the alimentary canal, and cut it open from end to end. The gizzard and other parts should be examined with the microscope. Each malpighian tube is accompanied in its whole length by a fine tracheal filament; this demonstrates how the air-tubes replace the circulatory system. The salivary glands are very beautiful objects beneath the microscope, and will teach the student the nature of gland tissue. The gland cells, with their contained secretion, which is seen as large bright granules, and their relation to the duct into which the secretion is poured, can be seen with much satisfaction.

Respiratory System.—The stigmata, or outer openings of the tracheal tubes, have been examined. The tracheal tubes ramify through all the body; among them may be mentioned one on either side close to the body wall, which places the several stigmata of a side in communication with one another; also four large tubes which

surround the oesophagus as it enters the head, and a pair of smaller tubes which lie one on either side of the ventral nerve-chord. The tracheal tubes are lined by a spiral thickening of chitin, which acts like a spring, and prevents the tube from collapsing; this may be pulled out from the tube like a coiled thread. The air in the tubes is renewed in the following manner. The abdomen is compressed by dorsoventral expiratory muscles. This movement drives air out of the tubes; when the muscles become relaxed, the tubes regain their normal size owing to the elasticity conferred by the spiral thickening.

Nervous System.—This is of the usual Arthropod type. The ventral nerve-chord in the abdomen is already exposed. In the thorax it is obscured by muscular bands, which must be cleared away; the ventral nerve-chords in the neck are freely exposed after the removal of the crop. They must be traced upwards until they enter the head. The epicranium must now be removed in order to see the cerebral ganglia which lie among fatty material opposite the fenestra. The ganglia are a pair of conspicuous spherical bodies, each of which is divided into two lobes, an olfactory lobe which supplies a nerve to the first antenna, and an optic lobe which sends a nerve to the eye of the same side. There is a system of gastric nerves connected with the crop; this consists principally of a small ganglion, which lies upon the oesophagus in front of the brain and gives off a

median nerve which passes beneath the brain and divides into two branches to end in the walls of the crop. The cerebral ganglia communicate by the circumoesophageal commissures with the suboesophageal ganglia, which supplies nerves to the mouth parts, and is joined by the ventral chords of the neck.

There is a large ganglion in each segment of the thorax; the ventral nerve-chord in this region is obviously double. In the abdomen there are six ganglia united by a chord which to the naked eye appears single; the sixth ganglion gives off two nerves posteriorly which diverge.

The Generative Organs.—These are found in the posterior end of the abdomen. In the female there are a pair of large ovaries, a spermatheca, and a pair of colleterial glands. The ovaries each consist of eight egg tubes, which are separated from one another except at their ends; at one end they unite in the oviduct, at the opposite end they come together and taper to a point. Each egg tube presents a beaded appearance due to the contained eggs, which increase in size towards the oviduct. The oviducts are a pair of short, capacious tubes which unite in a common opening on the 8th segment. The spermatheca is a small club-shaped body which lies close behind the sixth ganglion of the abdomen; it opens behind the oviducts. The spermatheca has a short, narrow, coecal outgrowth, and therefore resembles the spermatheca of many of the earth-worms. The colleterial glands are a pair of conspicuous tree-like organs, which lie on either side of the rectum; the one on the left side

is much larger than the other: they open separately behind the spermatheca. These glands secrete the egg capsule. The eggs are laid sixteen at a time (*i.e.* one from each egg tube), and are enclosed together within a large oblong capsule. While the capsule is being formed it lies within the brood pouch, but projects from it before completion.

The generative organs of the male consist of the testes, vesicula seminalis, and conglobate glands. The testes and their ducts are very difficult to see in the adult; they lie among the fat body beneath the fifth and sixth terga; their ducts are fine threads which open into the vesicula seminalis. This vesicle is also known as the mushroom-shaped gland; it is a conspicuous white-tufted body with a stalk-like duct which opens below the anus. The conglobate gland is a large club-shaped organ which lies beneath the posterior end of the nerve-chord; it often extends as far forward as the fifth ganglion, and usually lies to the left of the middle line; it opens independently below the anus. In both sexes there are a number of chitinous outgrowths in the neighbourhood of the generative apertures; these are the gonaphophysis.

THE MOSQUITO (*Anopheles rossii*)

The study of mosquitoes is important to the medical student, for it is these insects which by their bite infect man with malaria. The student must learn to recognize the Anopheles mosquito at all stages of its life-history,

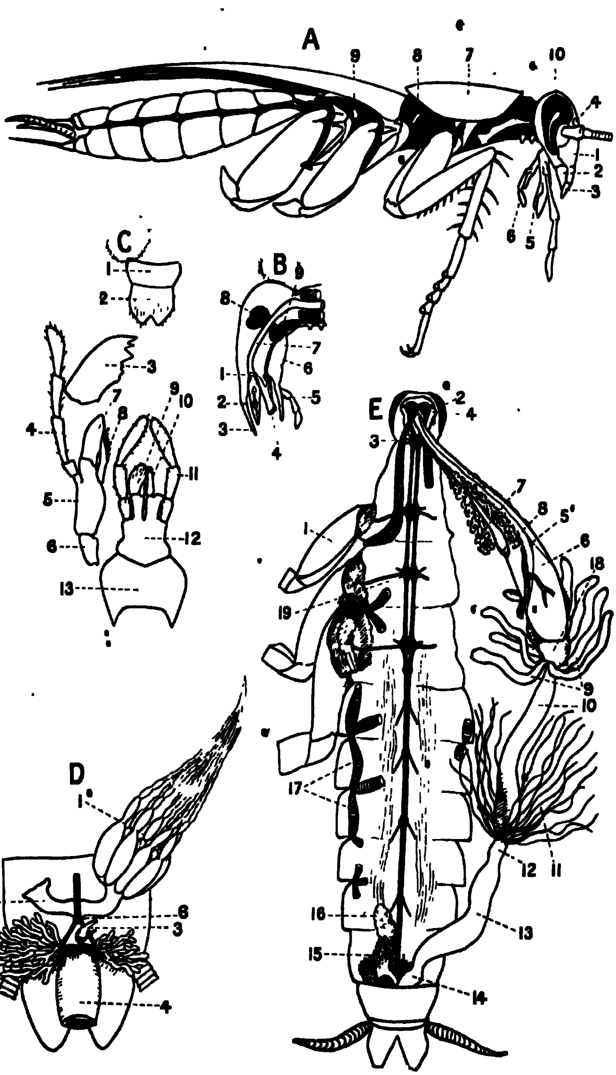
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PLATE XII.

THE COCKROACH (*Periplaneta australis*).

A. 1. clypeus; 2. mandible; 3. labrum; 4. fenestra; 5. maxilla; 6. labium; 7. pronotum; 8 and 9. thoracic stigmata; 10. compound eye. (Soft membrane of thoracic wall is black.)

B. Median section through the head. 1. the mouth; 2. mandible; 3. labrum; 4. lingua, 5. labium; 6. salivary duct; 7. oesophagus; 8. brain; 9. suboes. ganglion.

C. The mouth parts. 1. clypeus; 2. labrum; 3. mandible; 4. maxillary palp; 5. stipes; 6. cardo; 7. galea; 8. lacinia; 9. paraglossa; 10. glossa; 11. labial palp; 12. mentum; 13. submentum.

D. Female generative organs. 1. ovary; 2. oviduct; 3. spermatheca; 4. rectum; 5. colleterial glands; 6. terminal ganglion. (Right ovary has been removed.)

E. Dissection of male cockroach. 1. 1st thoracic leg; 2. eye; 3. suboes. ganglion; 4. cerebral ganglion; 5. gastric ganglion; 6. crop; 7. salivary gland; 8. salivary vesicle; 9. hepatic coeca; 10 mid gut; 11. malpighian tubes; 12. small intestine; 13. large intestine; 14. rectum; 15. seminal vesicle; 16. conglobate gland; 17. tracheal tubes, 18 gizzard; 19. thoracic ganglia.

because they are different among the several species. A short distance behind the brushes are the antennae, which project prominently on either side of the head and end in a pair of lanceolate scales and a branching hair. Between the bases of the antennae are six branching hairs set in a line across the upper surface of the head. On the sides of the head behind the antennae are the large compound eyes. Between the eyes are patches of pigment, which are arranged in a variable but symmetrical pattern.

In order to see the mouth the larva must be examined from the ventral aspect. The mouth is flanked by a pair of mandibles and a single pair of maxillae, which bear a large palp. There is a small pointed labium, or lower lip, behind the mouth. The thorax is nearly globular, and shows no sign of division into three segments. It bears several groups of long branching hairs, the arrangement of which is shown in the diagram. The abdomen consists of nine separate segments. On the upper surface of each segment from the second to the seventh is a pair of "palmate" hairs, which resemble the leaves of the tari palm. On the upper surface of the 8th segment are the openings of the trachea; these openings lie upon a kind of plate which is separated from the 9th segment by a deep groove, and has a dentate margin. The 9th segment bears three or four stout branching hairs, which protrude behind; and a kind of rudder, which projects ventrally in the middle line and also carries long branching hairs.

The anus is at the end of the 9th segment; on either side of it is a pair of papillae.

Growth and Habits of the Larva.—A living larva should be placed in a glass of water and carefully examined. When undisturbed, it usually lies at the surface, close to the water's edge. The water should be looked at from below, so that the under surface reflects light like a mirror. When the larva has risen to the surface it lies parallel with it, and its back seems to project from the water; this is because the palmate hairs break the surface film. Immediately the animal arrives at the surface, it twists its head completely round, so that the ventral or oral face is uppermost, and executes rapid movements with the brushes, as though sweeping a mirror. The surface of putrid water is covered with a film of minute organisms, seeking light and air, it is these which the larva sweeps into its mouth by means of its brushes. When disturbed, it glides with a twisting movement along the surface, or descends in the water. Larvae of all sizes have a frequent habit of bending the head round until it meets the tail; this is probably to clean the tracheal openings. As the larva grows it frequently casts its skin. The time which is occupied in attaining full growth depends upon the temperature, which influences the amount of the available food. The period is probably never less than a week, but it may be prolonged for eight months in temperate climates. The period in India is usually from a week to ten days. Growth is rapid in water

containing rotting leaves, especially when the weather is warm. If mosquitoes are allowed to deposit their eggs in an infusion swarming with Paramoecia, it will be found that when the larvae are mature, scarcely a single Paramoecium remains in the infusion. When the larva has attained its full size, it sometimes shows a tendency to sink in the water, and to hang vertically from the surface; when this stage is reached, it will throw off the last larval skin and appear as a pupa.

THE PUPA.—The pupal stage is one of rest. The pupa does not possess a mouth or an anus; the only openings are upon a pair of syphons, through which air is admitted to the tracheal system. The outer covering of the pupa protects the body of the Anopheles, while it undergoes a complete rearrangement, which results in the formation of the organs of the imago. The pupa consists of a swollen ovoid body, which contains the head and thorax of the mature insect, and a jointed, tail-like appendage, which contains the abdomen. The eyes, antennae, mouth parts, wings and limbs of the mature insect can be seen through the pupal case. The respiratory syphons are attached, one on either side, behind the eyes; they are somewhat like a cone of twisted paper from the rim of which a large piece has been cut out; there is a joint in the middle of the length of each.

The tail is held bent under the head, so that, to the naked eye, the animal looks like a comma. The tail or abdomen contains nine segments, and is provided

with several hairs, the most conspicuous of which are some stout, black bristles protruding from the sides. There is a pair of such bristles in each segment; those on the last or 9th segment are branched. The tail ends in a pair of elongated plates, by means of which the animal swims. When undisturbed, the pupa remains just below the surface of the water; the margins of the respiratory syphons break the surface film so that air can enter the tracheal system. The pupal stage is of very short duration; in tropical climates it usually occupies forty-eight hours, but it may be shorter even than this. The pupal case splits, and the imago comes out from it; this usually occurs towards evening, but it may occur at all times, even in strong sunshine.

THE IMAGO.—Mosquitoes belong to the order of the Diptera, which also includes the common house flies. Most winged insects possess two pairs of wings, but dipterous insects have only one pair. In place of the second pair, they possess organs called haltores, which are somewhat like drum-sticks in appearance. The body of the mosquito consists of a head, thorax, and abdomen. The head bears the stylet-like mouth parts, with which the female mosquito pierces our skin, injects the secretion of its salivary gland, and sucks blood for its food. The elongated mouth parts of the mosquito, at first sight show no resemblance to the short biting organs of the cockroach. The mouth parts of the bee are intermediate in type between the two extremes, for the mandibles of the bee are short, dentate pieces, as in the cockroach,

but the maxillae are elongated structures, which are used for licking up pollen and honey.

Examination of the imago must be made under the low power of the microscope.

Head of the Female Anopheles.—The sides and part of the upper surface of the head are occupied by the large compound eyes, which are nearly in contact with one another, both above and below. The eyes are separated posteriorly by a V-shaped area called the vertex, which is covered with long, hair-like scales. In front of the eyes is a triangular area which is prolonged anteriorly into the clypeus, a lobe overhanging the bases of the mouth parts. The antennae are attached in front of the eyes; they are composed of fifteen segments: the 1st or basal segment is expanded. Each joint of the antenna is encircled by a row of small hairs. The mouth parts are nine elongated rods of approximately equal length, seven of which are included in the proboscis. These seven are the labium, the labrum, and hypopharynx, the two mandibles, and the two maxillae. The labium, which is homologous with that of the cockroach, is posterior to the others. It is terminated by a pair of short, leaf-like pieces called the labellae. When the animal sucks blood, these labellae rest upon the skin of the victim; the stylets are pushed between them and enter the skin. The labium does not enter the skin, and must therefore be bent backwards like a bow when the other parts are thrust deep into the skin. The anterior side of the labium is a deep groove in

which the other mouth parts lie; the other sides of the labium are covered with scale-like hairs. The labellae are white; the rest of the labium is black. The six pieces which enter the skin of the victim in biting are the labrum, the two mandibles, the two maxillae, and the hypopharynx, or tongue.

The Labrum.—This is anterior to the others. It is a hollow cylinder or tube, open by a slit on the posterior side; the end of it is pointed. It is comparable to the labrum of the cockroach, for its posterior surface, *i.e.* the inner surface of the tube is continuous with the lining of the oesophagus. In feeding, blood and other fluids pass up this tube into the oesophagus.

Hypopharynx (or Lingua).—This lies posterior to the mouth, between it and the labium, that is to say, in the same position as the lingua of the cockroach; but, whereas in the cockroach the duct of the salivary glands opens at the base of the lingua, in the mosquito it opens at the apex. The hypopharynx is like a straight but flexible two-edged sword. Under the high power of the microscope the salivary duct can be seen in the axis of the organ.

Mandibles and First Maxillae.—These are two pairs of stylets, each of which is armed near its termination by a row of saw-like teeth, and ends in an acute point. The ends of the mandibles are straight and very finely serrated. The maxillae are curved towards their ends; their serrature is coarse, and placed on the convex side of the curve; when, however, the maxillae are not

properly flattened, the teeth appear under the microscope as though placed on the concave side. The maxillary palps are covered with hair-like scales. Each palp is composed of four segments. In Anopheles rossii the whole of the small terminal segment of the palps, as well as part of the next, are white, and there are two other white bands situated at the other joints.

Head of the Male.—The male can be distinguished from the female with the naked eye. The antennae are longer and more plentifully provided with hairs. The maxillary palps are longer, and the last two joints are broad and conspicuous. There are no mandibles in the male, and the hypopharynx is fused with the labium.

Thorax.—The thorax is like a pyramid with the apex placed ventrally; it is the largest part of the body. As in all insects, it consists of three segments: the pro-, meso-, and metathorax, each of which bears a pair of legs. The mesothorax is provided with a pair of wings, and the halteres take the place of the posterior or metathoracic wings of other insects. There is difference of opinion as to which of the various plates forming the wall of the thorax belong to any particular segment. When viewed from above, the thorax appears threefold; the anterior division occupies more than three-quarters of the whole; it may be called the pronotum. Posterior to it is a narrow band, the mesonotum, on either side of which the wings are attached. Posterior to this is a curved heart-shaped plate, which may be called the metanotum, on either side of which are the halteres.

As in the cockroach, there are two pairs of tracheal openings, or stigmata: the anterior pair are much the larger; they are placed near the centre of the side wall of the thorax. The posterior smaller pair lie below the halteres.

The Wings and Legs.—The spotted feathery appearance of the wings is very characteristic of the Anopheles. The wings are supported by nervures, to which lanceolate scales are attached; the nervures have received names which are of systematic importance. The student should observe that the front margin is composed of a feathered nervure, close behind which is another lying parallel with it in its whole length; between the two, and partially hidden by them, is a third nervure, which is only about half the length of the others. Posterior to these are five other nervures, three of which are forked; two of them are incomplete, and do not reach to the base of the wing. Besides these there are four very short transverse nervures, which unite and strengthen certain of the longitudinal ones. The three pairs of legs are attached close together to the apex of the thoracic pyramid; in their segmentation they resemble the legs of the cockroach, except that the coxa is relatively much shorter and the tarsus much longer. The pigmentation of the legs differs in the several species. In A. rossii all the joints between the several segments of the limbs are white, but the segments are pigmented.

Abdomen.—Consists of eight segments, each protected by a dorsal tergum and a ventral sternum. On either

side is a row of six stigmata; they are hidden and difficult to see. In the male the abdomen terminates in a pair of pointed organs called claspers, which are bent inwards towards one another. In place of them in the female are a pair of lobes, or ovipositors.

INTERNAL ANATOMY.—Although the internal anatomy of so minute an insect is difficult to study, the alimentary canal can be easily examined, and it is important that the student should be able to perform the dissection necessary to display it. Remove the legs and wings from a freshly killed mosquito, and place the body in a drop of salt solution upon a glass slide. With needles or forceps pull the head from the thorax. It will generally be found that the salivary glands and part of the oesophagus remain attached to the head, and hanging from the stump of the broken neck.

Salivary Glands.—The salivary glands are six finger-like bodies, each of which is a tubular gland. The glands should be cut away from the head with a needle, covered, and examined under the high power. The cells of which they are composed contain oval drops of an oily secretion, which may be so large as to occupy nearly the whole cell. Among these cells the filiform sporozoites are found in mosquitoes which are infected with malaria. The salivary glands lie naturally within the anterior part of the thorax, three on each side. Each group of three pour their secretion into a single duct; the ducts of either side unite in a common duct, which enters the base of the hypopharynx and opens at

its apex. The three glands of a side are not all alike. The middle one, which lies between the other two, differs from them in the appearance of its cells. It is probable that this middle one represents the salivary receptacle of the cockroach, which lies between the two glands of a side.

The Mid-gut, etc.—In order to display the remainder of the alimentary canal, the abdominal wall must be incised about halfway between the middle of its length and the posterior end. In order to do this, place the decapitated mosquito upon a glass slide in a drop of salt solution; take a fine needle in either hand, and at the spot selected for incision lower the points of the needles on to the margins of the abdomen, and press them against the glass. Having incised the abdomen in this manner, transfix the thorax with one needle close to the bases of the legs, and place the other needle on the terminal segment of the abdomen. Press the points of the needles firmly on to the glass, and draw them apart. The alimentary canal will be dragged out of the thorax and larger part of the abdomen, but will remain attached to the terminal segment. The anterior broken end of the alimentary canal will generally be found to fit the broken end of the oesophagus, which is attached to the head, so that the whole length of the canal is displayed lying in salt solution. If the mosquito is freshly killed, active peristaltic movements will be seen in the mid- and hind-gut.

The most noticeable part of the canal is the mid-gut,

a pyriform sac which is of a narrow girth anteriorly, and widens out towards its posterior attachment; at its anterior end is a small proventricle (homologous with the gizzard of the cockroach). The posterior end of the mid-gut joins the hind-gut; at the junction five long malpighian tubes are attached. The malpighian tubes are visible to the naked eye as white threads; their component cells are so large as to be easily distinguishable under the low power of the microscope.

Anterior to the proventricle is the crop, a voluminous thin-walled tube, to which is attached one or more air sacs. There is always a large air sac attached near the proventricle, and there are often one or two smaller ones further forwards. These sacs usually contain air bubbles, but they may contain blood after the mosquito has fed. The large sac is visible to the naked eye as a silvery white spot.

Habits of the Imago.—Mosquitoes of this species may be found throughout the year in Calcutta, but they are particularly common indoors at the commencement of the rainy season. They are to be found resting during the day in dark corners, especially under the low roofs of huts and cowsheds, but they are liable to be overlooked because of their resemblance to the pointed ends of nails, which one naturally expects to find in such places. Anopheline mosquitoes have this appearance because the axis of the body is held nearly at right angles to the surface upon which it rests. By their attitude they may be distinguished from culicine mosquitoes, which

rest, with the body close to the surface, and more or less parallel with it. The characteristic attitude of the resting Anopheles is a useful aid to identification, but it is not invariable. Culex, however, always looks "humped-backed," because the proboscis and the body meet at an angle, whereas in Anopheles these parts lie in a straight line. Conflicting statements have been made about the development and deposition of the eggs; it is probable that these events vary considerably in the various species and under different conditions, such as temperature and food supply. After leaving the pupa mosquitoes are soft, and cannot feed until several hours have elapsed. The male mosquito does not feed upon blood, but upon sugary juices. The female also will feed upon sugar, but it is very eager for blood, which is its principal food. The eggs inside the body of a new-born mosquito are very small, and it is most probable that they cannot become mature unless the insect obtains at least one meal of blood.

In captivity, and probably under nature also, the male mosquito is short lived; the female, however, may live, even in captivity, for more than a month. In an experiment conducted in Calcutta during the month of September, a large number of A. rossii were hatched out and kept in a bottle over water. They were supplied with sugared fruit for food, and allowed to suck blood every second evening. Most of the males died during the first night, but three of them lived for nearly a week. The eggs of the females did not attain the mature size

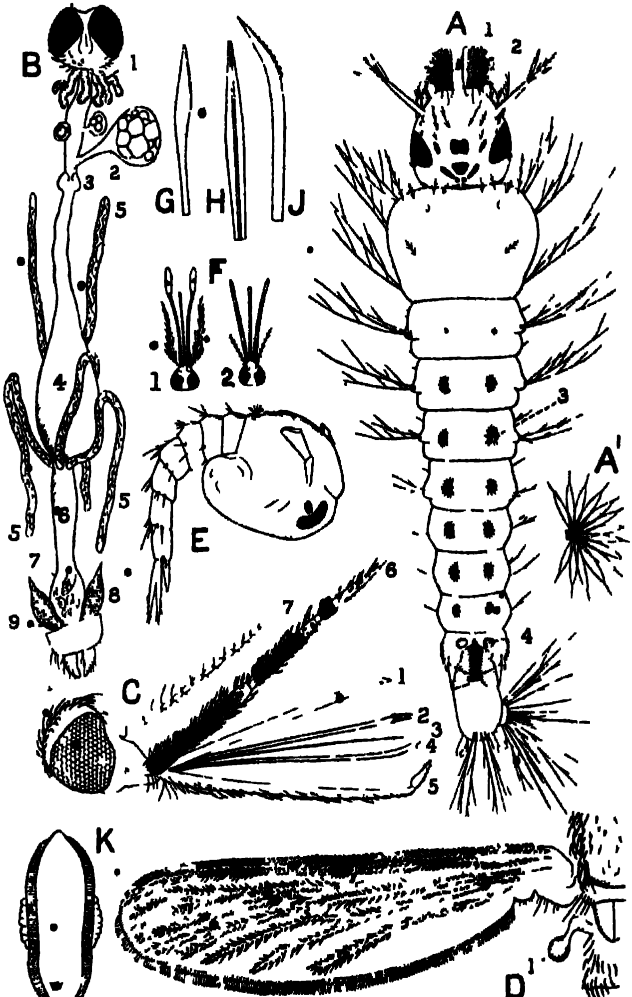
until the tenth day, but none of them were deposited, although several of the insects were alive on the twenty-fifth day, when the experiment was accidentally terminated. It is important to consider the means by which mosquitoes are disseminated. There is no doubt that they may be carried by a gentle steady breeze to a distance greater than ten miles from their birthplace. The larvae are often disseminated in transported drinking water.

The egg of an anopheline mosquito is somewhat less then a millimetre in length, but it is easily visible to the naked eye; at the time of deposition it is white, but it darkens soon after; it is boat-shaped, and is provided with a bladder-like float on either side. The eggs are deposited by the mosquito not only at the surface of water but also on wet mud, in which case they may be inundated by a shower of rain. If the mud dries the eggs perish.

PLATE XIII.

THE MOSQUITO (*Anopheles rossii*).

A. The larva. 1, 2. clypeal hairs; 3. palmate hairs; 4. opening of tracheal system.
A[1]. Palmate hair × 500 (apx.).
B. The viscera. 1. salivary glands; 2. oesophageal sac, containing air; 3. proventriclo; 4. mid-gut; 5. malpighian tubes; 6. intestine; 7. rectal papillae; 8. ovary; 9. spermatheca.
C. Head of female. 1. labrum; 2. mandibles; 3. hypopharynx; 4. maxillae; 5. labium; 6. maxillary palp; 7. antenna.
D. A wing. 1. haltere.
E. The pupa.
F. Head of male, 1; female, 2.
G, H, and J. Mandible, hypopharynx, and maxilla, highly magnified.
K. An egg × 35.



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CHAPTER VIII

THE UNITY AND DIVERSITY OF LIVING THINGS

Biology is the study of living things, of animals and of plants. It is the custom to treat zoology, the study of animals, separately from botany, the study of plants. But students of either of these sciences are dealing essentially with the same thing, in that they are studying living things. The great activity which has occurred during the last century in the study of animals and plants, whether of their structure, functions, growth, or reproduction, has led us to believe that there is a unity among all living things, and that man himself, though so complex and important, is of one nature and origin with the others.

Let us consider some of the resemblances which all living things bear to one another. They are composed principally of living material, a soft colourless translucent and granular substance which is insoluble in water. This substance, which is called protoplasm, possesses certain properties which may be spoken of collectively as the manifestations of life. It is apt to lose these properties and become lifeless. The nature of the change which protoplasm undergoes when it becomes lifeless is

quite unknown to us; it seems to be a sudden and irrevocable change. As lifeless material it can be analyzed by the chemist. It contains more of water than of any other constituent; substances named proteids are, however, its most important constituents. The albumen of a bird's egg is a proteid. Proteids contain the elements carbon, hydrogen, nitrogen, oxygen, and sulphur. Owing to the difficulty of obtaining them in a pure state they cannot be analyzed satisfactorily. As obtained from lifeless protoplasm proteids are found to contain small quantities of such elements as calcium, potassium, sodium, phosphorus, and iron, elements which are known to have important functions to perform.

Throughout life protoplasm undergoes certain internal changes which are spoken of as metabolism. This we know by observing that it takes in some kinds of material from the outer world and gives out other kinds, while at the same time it may increase or grow. From the way in which these changes are known to us, we assume that they must be twofold in nature—a building up, or constructive, process, and a breaking down, or destructive, process. These are to some extent independent of one another, for the destructive process can occur alone for a time. In the study of metabolism it is the custom to recognize two kinds of changes, called respiration (breathing) and assimilation (feeding).

Respiration.—Respiration is the same process in almost every kind of animal and plant. The outward result of the process is that the protoplasm is oxidized,

that is to say, it takes in and combines with the oxygen of the air, and also gives out carbon dioxide and develops heat. Respiration therefore resembles the process of combustion. It is assumed that the energy which is shown by protoplasm originates in the process of respiration, just as the energy of a steam engine originates in the oxidization of coal.

Some few organisms, such as yeast and certain bacteria, may live without oxygen, while they give off carbon dioxide in large quantities. In these, protoplasm must itself supply the oxygen of the carbon dioxide, oxygen, which it cannot have obtained directly from the air. A frog cannot live for very long without oxygen, but if it be placed in an atmosphere of pure nitrogen it will live for some hours, during which it will continue to give out carbon dioxide. The oxygen in this case must also be derived from the destruction of protoplasm. We see from this that though respiration resembles combustion in its results, the two processes are far from being identical, since combustion cannot occur without oxygen. However, it is certain that almost all living material has an inherent desire for oxygen, which is similar in effect to that possessed by many chemical bodies. An amoeba, which consists merely of a small piece of living material, absorbs oxygen directly from the outer world; but in the higher animals oxygen enters the body through special organs, called lungs or gills, and is carried from them by means of blood-vessels to the protoplasm.

Assimilation.—Though respiration is, with few exceptions, one process in all living things, assimilation is not so. This seems to be necessary, for whereas in respiration the intaken material (oxygen) is in all cases equally available and the same, in assimilation, owing to the different conditions in which living things occur, there is very great variety in the kind of material (food) which is available. There is in the first place a broad difference between this process in animals and plants, and some difference in detail among the different kinds of both. One part of the process, however, is the same in all, for water is taken in by every kind of protoplasm, and is indispensable to all living things. The broad distinction between the method of assimilation in plants and animals is that the former can take simple substances, such as carbon dioxide and simple salts such as the nitrates, and can build these substances into its protoplasm. This process is not accompanied by an obvious formation of nitrogenous waste products. Animals cannot make use of simple substances for their assimilation, but take the required materials, such as carbon in the form of starch or sugar, and nitrogen in the form of complex proteids, the lifeless protoplasm of other animals or of plants; this intake is accompanied by the output of large quantities of nitrogenous waste material. Like respiration, the process of assimilation is performed directly in the lowest animals, indirectly in the higher animals by means of an alimentary canal and blood-vessels. The student must remember that

respiration and assimilation occur in every particle of living material. Organs such as the alimentary canal, the lungs, gills, and blood-vessels are merely the paths by which oxygen and food materials are carried to the protoplasm or seta of metabolism.

Movements.—Various movements, both external and internal, occur in all living things. It is probable that all living material undergoes internal movement, though it is usually slow and difficult to see. Streaming movements in simple animals and circulation of protoplasm in plants can be easily watched under the microscope. Most animals can, of course, move from place to place, while all but the lowest plants are stationary. This is associated with their respective methods of assimilation. A plant is always bathed in its food: its leaves are surrounded by gases, its roots by water containing the necessary salts; but an animal must seek its food.

Irritability.—Living material is acted upon by the external conditions among which it lives, and so far as we know, any one kind of material is always acted upon in the same way by any particular condition; if it were not so, it would be impossible or useless to study life. The streaming movement of protoplasm always responds in the same way to heat, which may be chosen as an example of a changing external condition. If the temperature be raised, the movement becomes quicker, but it becomes slow again when the temperature falls. Different kinds of protoplasm are acted upon in different ways by the same condition: some kinds of simple

organisms always move towards light, other kinds always move away from it. This response to external conditions is called irritability: it is an attribute of all living material. Although the primary cause of this activity in response is obscure, its meaning is often plain, for frequently we can see that such activity is directly for the benefit of the organism, and we may infer that it is generally so. Green plants turn to the light, because without light they cannot assimilate. Amoebae move towards food, and away from harmful substances. All organisms which are able move hurriedly from burning heat. There are, however, certain accidental exceptions to the rule that animals respond to the conditions only for their benefit; for example, night-flying insects move so eagerly towards the light of a burning substance that they cannot stop themselves when repelled by the heat, and become burnt to death. In this case the attraction of the light is certainly harmful, but we must remember that night-flying insects probably became endowed with their peculiar fondness for light long before man first used artificial light and fires, and it is possible that the night insects' fondness for light is of benefit in the absence of artificial light; it might induce them to congregate in moonlit patches of the jungle, congregation being necessary for breeding. We may feel sure that the response which the various forms of living things show to the external conditions is generally for their own benefit; exceptions to this rule are accidental, as in the

case just described. Although there is unity in living matter, there are a vast number of different forms of it; the animals and plants we know, each of which responds to the conditions which surround it. The different forms are such that they are generally suited or adapted to the different conditions of the outer world. Many biologists think that the question as to how this state of adaptation came about is the most important problem in biology. We shall return to this question in the next chapter. We have mentioned that one condition, such as light, may influence different kinds of living material in different ways. The student will also learn that different conditions acting on the same kind of material sometimes produce the same effect. A muscle can only respond in one way, namely, by contracting, although it will respond to many different conditions. If in a room where no light enters, we press the side of the eyeball with a hard point, as of a pencil, we see a spot of light. As the point is moved while pressing so the spot of light moves; it is therefore caused by the pressure of the pencil. The nerve which spreads over the back of the eye, though commonly responsive to light, is also responsive in the same way to pressure. It seems to be neither beneficial nor harmful that the optic nerve should respond to pressure as well as to light.

CELLS.—We have seen that all organisms are composed principally of living material. We shall now consider how this material is arranged. It is only since the invention of the microscope that this has been

understood. Protoplasm when dead can be examined in minute fragments, or in very thin slices with the help of the microscope. Just as a house is built of bricks and beams of wood, units of lifeless material, so is every organism composed of units of living material. The living material of all animals and plants, except the simplest, is divided into a great number of separate units, called cells. In the higher organisms there are a vast number of these cells, which are of many different kinds. In the simpler organisms there are fewer. The body of a Protozoon is one cell, although it can perform the several functions which are carried out in the higher animals by many different kinds of cells. The word "cell" does not seem a good one to describe a piece of any material, as it suggests a small space enclosed by walls. The misnomer arose in the following way. Each cell of a plant forms for itself a coat, or cell wall; the walls of adjacent cells are firmly pressed together, and constitute a structure resembling a bee's honeycomb. This can be seen with the help of a simple lens, and was the first observation made in the minute structure of living things. At first the living material which is contained in these vegetable cells was not seen. We now know of its existence, and regard it as of the highest importance. The cells, both in animals and plants, are not entirely distinct from one another; they are not merely in contact with one another, but are united by fine threads of living material which, in plants, pierce the cell walls. Any one previously unacquainted with the subject can

easily satisfy himself that his own body is composed of cells. If the inside of the cheek or lip be gently scraped with a sharp knife, an abundant greyish deposit collects on the knife edge. If this deposit is examined with a microscope, it will be found to consist of thousands of colourless translucent bodies, which are flattened and nearly circular in outline, and resemble one another very closely. These are cells which were detached by the knife.

The Nucleus. The fact that the material of which all but the simplest organisms are composed is divided into a great number of separate cells confers a degree of unity on all living things. This unity is much strengthened by the fact that every cell contains a small round body called the nucleus. Although there are many different kinds of cells, all of them contain nuclei, which are with few exceptions identical in structure. The fact that the nuclei of the cells which compose a tree, a herb, a worm, or a man are alike in their visible structure confers a wonderful degree of unity on the whole.

It has been mentioned that protoplasm increases or grows; cells must therefore grow. In plants, growth occurs at special points, and continues throughout the whole life of the plant; in animals, it is not confined to special parts, nor does it continue throughout life. Growth is always accompanied by cell division; it seems as though a cell cannot be of more than a certain size: it must divide and become two cells. Division of the

cell is always preceded by division of the nucleus. The nucleus divides in a complicated, though definite, manner, which is the same in all living things. Nuclear division of this kind is called mitosis. The most noticeable constituent of a nucleus is a substance called chromatin, which has the property of absorbing certain dyes to a greater extent than any other part of the cell. Owing to this property, chromatin can be rendered visible in a cell, and finely examined with the help of the microscope. Except when the nucleus is about to divide, the chromatin of which it is composed has an irregular, net-like appearance. Before division, it undergoes certain changes, and becomes resolved into a number of separate bodies, each of which is like a bent rod or loop. These rods are called chromosomes. As mitosis proceeds, each chromosome divides in its whole length, just as a log of wood is split by wedges. Each half resembles the whole from which it was derived. The number of chromosomes present in the dividing nucleus is therefore doubled. As soon as the division of each chromosome is complete, the halves move apart from one another. As there are several chromosomes originally present in the nucleus, and each one divides, two sets of halves result from the divisions. The members of each set collect together, and lose their rod-like shape. They become net like, and constitute the nuclei of the two new cells which result from the division of the old one.

It is believed that the number of chromosomes

present in every cell of any one kind of organism is constant. The number may be as few as two, or as many as two hundred. The number of the chromosomes has no relation to the kind of organism in which they occur. It often happens that organisms which are very unlike one another have the same number; on the other hand, organisms which are very closely alike do not always have the same number. The number of chromosomes present in an organism must be of an even number; in other words, it must be equally divisible by two. The reason of this will be seen later on.

Reproduction.—Each individual organism can live only for a limited time. New ones are produced, and take the place of those that die. With few exceptions, the method of this reproduction is essentially the same in all living things. We have seen that all organisms are composed of cells which are of different kinds, different in appearance and in the work which they perform; of these, the most important are the germ-cells which are set apart for reproduction. Germ-cells become separated from their containing parent organism; they grow and form the offspring. The germ-cells are therefore the most important cells in the body. They are regarded as something different in kind from the other cells of the body. In order to emphasize the difference, the name soma has been given to every part of an organism which is not germ. Any organism, therefore, consists of germ and soma; during the life

of the organism, some of the germ-cells become separated from the soma, and give rise to new organisms, each of which also consists of germ and soma. In each generation the containing soma, or body, dies; but the germ is continuous from generation to generation. The particular qualities of any organism seem to be concentrated in its germ. The relation between the material germ and the many qualities which it conveys is, I think, quite unknown to us, although it has been the subject of much speculation. The germ is contained among the soma in the same way in almost all animals and plants. It occurs in two kinds of cells, which are called the male and female gametes. These usually occur in separate individual bodies, but they are often borne by one and the same, which is then called hermaphrodite. The first stage in the development of the offspring from the germ is the union of two gametes. The gametes are brought together in various ways among the different kinds of organisms, but the union of the gametes is essentially the same act in all cases. From this union a body called a zygote results. The complete zygote consists of one cell containing a single nucleus; it gives rise to the many-celled offspring by cell division and growth. Early in the process of development, the germ-bearing cells or gametes which will give rise to the following generation can often be distinguished among the others. Although the zygotes of different kinds of organisms originate in the same way, and are often closely alike in size and outward

appearance, we know that in some invisible way they must be entirely different from one another, for each kind produces its own kind of organism—a tree, a fish, or a bird, as the case may be.

What is it that determines the course of the development of each kind? It has been suggested that the determinant is contained in the nuclear material. This idea arose as a result of the study of mitosis in the following way: An offspring may be regarded as a combination of its parents. In its general appearance it obviously resembles the class to which they belong, but it may show the special slight peculiarities of one or other, or of both. The contribution of both parents to the heritage is not necessarily equal, but both contribute to it; one sex does not regularly contribute more than the other. Bearing this in mind, we will now consider the structure of the gametes. In all but the lowest organisms these cells are quite unlike one another as regards their outward appearance. The female gamete, the ovum or egg-cell, as it is often called, is usually many times larger than the male gamete, owing to the excess of protoplasm which it contains; it also often contains a store of material, called yolk, as food for the embryo which is to be developed. On the other hand, the male gamete, or spermatozoon, is very minute, and is provided with some contrivance to enable it to move towards the passive ovum.

The two kinds of gametes, so unlike one another in

most respects, are nearly always alike as regards their nuclear material. The first stage in the development of most organisms is the union of an equal number of chromosomes derived from either parent. This fact, taken in conjunction with our common experience that either parent may contribute to the visible heritage of the offspring, and that one sex does not regularly contribute more than the other, gave rise to the idea that the determinant of the heritable qualities lies in the chromosomes; other facts support this idea. We do not understand the relation between the chromosomes and the qualities which they convey. We assume that there must be some slight material difference between those contained in the germ-cells of two brothers, for each may transmit his own peculiarities to his offspring. The difference between those contained in men of different races must be wider than in the case of two brothers. How wide, then, must be the difference between the chromosomes of a plant, of an insect, a fish, or a man! And yet chromatin appears and behaves outwardly as though it were one and the same substance in all living things.

It is very difficult to understand the meaning of mitosis, but we may feel sure that such a definite phenomenon, which occurs in almost all living things, is a visible part of the most important processes which occur among living things; we may also feel sure that the view of the process which we obtain with the help of even our most powerful microscopes is merely superficial.

Chromatin behaves chemically as though it were one substance in all animals and plants, but the process of mitosis itself makes us think that the nuclear network contains a great many different kinds of things, for the process is such that it is entirely suited to effect the complete division of a mixture of many kinds of things. If the network contained only a few kinds of things well mixed together, a simple division of the nucleus into two parts as with a knife, would effect a nearly equal division of its constituents. But if many different kinds of things were present, such a simple method would not bring about a division into two parts, so that each part contained some of every kind. To bring this about a more intimate method is required. The attenuation of the chromatin in the form of rods, and the equal division of these rods in their whole length, which occurs in mitosis, is eminently suited to the work of dividing a mixture of many kinds of things into two parts, in such a way that each part contains some of each kind. The following illustration will make this clear.

Take four hundreds of small cubes of wood, each hundred being of a different colour, the cubes of each colour bearing numbers 1 to 100. The whole will be made up of four different kinds of things, one hundred of each kind, if we regard colour; or there will be one hundred different kinds of things, and four of each kind, if we regard numbers. The whole are thoroughly mixed together, and poured out on to a table so as to form a square flat group. If the group be divided equally by a

line through the middle, it will be found that each half contains about fifty cubes of each of the four different colours. But as regards the numbers the division will be very incomplete. In some cases there will be no division, all four of a number being found in one or other half. Now, a more complete division of the many numbered groups can be brought about by a method which is comparable to mitosis. The group of cubes is made to undergo a preliminary division into a number of elongated sub-groups; the actual division is then performed on each sub-group in its whole length. This intimate method will effect a more complete division of the numbered groups than the simple method.

Mitosis is a subject of the highest importance in biology. Its meaning will become more fully understood as our knowledge of the process increases. Other important facts which are known or suspected regarding it may be briefly mentioned. The individuality of the chromosomes seems to persist through the so-called resting-stage of the nucleus, from one state of active mitosis to another; for when the chromosomes emerge from the net-like condition of the resting-stage, they may appear not only in the same number, but in the same relative position, and in the same individual shape, as they occupied before entering the resting-stage at the close of the previous division. Moreover, in some plants the chromosomes never fully enter the resting condition, so that they can be counted at all times.

It is well known that the number of the chromosomes

present in the gametes is always half that present in the other cells of the body. If the number of the chromosomes present in the body cells of a particular organism is twelve, the number present in the gametes will be six; when two gametes unite to form a zygote, the two sets of six become added together so that the nucleus of the zygote contains twelve, six of which are paternal, and six maternal. If it is true that chromosomes always preserve their individuality, it follows that every cell of the offspring which arises by the division of the zygote will contain six chromosomes derived from one parent, and six from the other. The nuclear substance must be capable of indefinite expansion by the building-up process of metabolism; but in spite of this, it seems to preserve its own special quality or determinative power. This quality is so varied that it is not necessarily identical even in two parents, and it seems that the two kinds, the maternal and the paternal, are contained in separate chromosomes in very cell of the offspring.

We will now briefly consider how the reduction in the number of chromosomes in the gametes is brought about. In ordinary mitosis the number of chromosomes always remain the same, because each one splits and the halves separate; but in that division, by which the gametes are formed, the chromosomes do not split individually, but half their number become separated from the other half, hence the number of chromosomes in the gametes is half that present in the body cells; this

particular division is called the reducing division. The reducing division occurs at different times in the life-history of animals and plants. In animals it occurs at the division which gives rise to the gametes, but in plants it occurs at the formation of the spores. The student will learn that the spores of a fern, on germination, give rise to a small structure called the prothallus, in which the gametes are produced. The spore and every cell which it gives rise to, contain the reduced number of chromosomes, hence the gametes contain the reduced number.

THE DIVERSITY OF LIVING THINGS

We know that living matter occurs in many different forms, and that no two living individuals are exactly alike. This fact must not be lost sight of. To be exact, the number of kinds of living things on the earth is the same as the number of individuals. It may be said that small differences are negligible, for no two things dead or living can be exactly alike; but we must not let this hide the fact of the individual differences of living things, for we can manufacture two lifeless objects of nearly the same size and material which are much more closely alike than are any two living things that can be found.

Among the multitude of different organisms we notice that some (*e.g.* twin-brothers) are very nearly alike, while

others (*e.g.* a man and a herb) are utterly unlike one another. In order to make this great diversity convenient to our minds we classify living things. We divide them at once into animals and plants, and we further subdivide these two kingdoms, as they are called. The subdivision is carried out in the following way. Let us regard the animal kingdom only. The body of many animals consists of one cell only; these animals form the group of the Protozoa. In others the cells of the body are arranged in two layers; these are the Coelenterates. There is never any doubt as to whether an individual is a Protozoon or a Coelenterate. In the same way any individual may be placed in a group: it is either an Annelid, a Platyhelminth, an Echinoderm, a Mollusc, a Crustacean, an Insect, or a Vertebrate. These groups are, for the most part, definite and distinct from one another.

Let us now consider, with a view to further subdivision, one of these several groups. We will choose the Vertebrates, as they are well known. Any animal which has a backbone, a spinal cord, and a skull containing a brain and organs of sight, hearing, and smell is a Vertebrate. But any vertebrate animal is either a fish, an amphibian, a reptile, bird, or mammal. Any of these lesser groups may again be divided. We will consider the mammals. Any animal which has hairs embedded in its skin and suckles its young is a mammal. For some mammals we use the terms horse, cow, dog, cat, rat, rabbit, but the differences which causes

us to apply these terms are not equivalent. We can see by a glance at the teeth and feet that the horse and the cow are more alike one another than they are to any of the others; the same is true of the dog and cat, the rat and rabbit. The mammals may therefore be arranged in groups, each of which may further be subdivided. These groups are called orders, and their subdivisions are called families; each family contains several genera, and each genus contains a number of species. In the middle of the eighteenth century, Linnaeus established the custom of designating every animal by two names: the first name denotes the genus to which the animal belongs, and the second denotes the species. For example, the lion, tiger, and leopard are very alike as regards the form of the skull, teeth, and feet, and in their anatomy generally; they are therefore said to belong to the genus Felis; but the tawny lion, with its mane, is called Felis leo, the striped tiger is called Felis tigris, and the spotted leopard Felis pardus. Every kind of animal and plant is named in this manner. This method of nomenclature is, however, purely arbitrary, that is to say, there can never be complete and final agreement of opinion as to the constitution of one of the specific groups. One naturalist may define a species in the following imaginary terms: "Every individual animal in the world which possesses certain particular features—of size, form, and colour—is of species Z" (for argument we will designate the features A, B, C, D). A second naturalist turns his attention to species Z, and replies to the first naturalist: "I have

collected some hundreds of individuals of your species Z. I can recognize them because they all clearly show the features A, B, C, D; but I find on minute examination some small points which you have overlooked. Some of them show a feature *a*; others do not show *a*, but show another feature, *b*; others again show both features *a* and *b*. I must therefore divide up the old species Z into three new species, *x*, *y*, *z*." A species is therefore a subjective thing, that is to say, it depends on the convictions and powers of observation of the person who is dealing with it, and must be accepted on authority, which changes from time to time. We must keep clearly before us, firstly, the fact that no two individual animals are exactly alike; secondly, that animals can be arranged in groups according to their resemblances. It seems impossible, however, to find a group which cannot be split up; even the children of the same parents may be classified; some may have blue eyes, while others may have brown eyes. It is the custom to speak of animals which closely resemble one another as being of the same species, but our idea of a species as depending on resemblances is arbitrary, and has arisen for our convenience in describing animals. Only those animals which are nearly alike will breed together and produce fertile offspring. We say therefore that animals which can breed together and produce fertile offspring are of the same species, but we must remember that such a group of animals may still be subdivided into lesser groups according to their resemblances and differences.

We have been considering each animal or plant as a unit of living material, and we have seen that these units can be distinguished from one another by the differences in form and attributes which they present, but we have assumed that the material of which they are composed is of one kind in all. A substance seems to be of one kind when we cannot distinguish separate kinds among it; and protoplasm as a substance has, until recently, seemed to be of one kind. During the last few years, however, we have learnt to recognize separate kinds among such products of living material as blood serum, milk, egg albumen, etc., by a newly discovered method which cannot be described here. The important part of this discovery is that the differences which can be recognized in the proteids are in the same relation to one another as the differences in the outward form of the animals which contain them. For example, we have long known that in their form, a goose and a duck are more like one another than either of them is to a hen, but we have not been able to see any difference between the albumen taken from the eggs of these three kinds of birds. By means of this new test we might be able, not only to distinguish the three kinds of albumen, but to recognize that the albumen of the duck and goose are more like one another than either of them is to that of a hen. This serves as an illustration, but it is not a good practical example. As practised at present, the test would probably indicate that the albumen of the duck and goose were indistinguishable from one

another, though both could be distinguished from that of the fowl. The blood serum of a man can, by means of this test, be distinguished from that of the lower animals. In future this fact may be of importance to many a man falsely accused of murder.

CHAPTER IX

EVOLUTION—ADAPTATION

WE see that animals after giving birth to others like themselves ultimately die. One generation replaces another. Our own lives are so short that we cannot watch more than a few passing generations in the history of any kind of animal or plant, and finding no marked difference between the members of a first and of a tenth generation, we may hastily and unjustly assume that if we could examine a thousand generations, there would in no case be any difference between the first and the last. If the process of reproduction is like the manufacture of a series of articles, each member of the series being an exact copy of its predecessor, it is plain that the first must be exactly like the last however large a number are manufactured. But we know that offspring and parent are not always closely alike, and it is now generally believed that if we could trace back the ancestral history of any organism far enough, we should find that great changes had occurred in it, and that the earlier generations would usually be simpler than their descendants. This idea is expressed by saying that living things have arrived at their present state by a process of evolution.

Owing mainly to the teaching of Darwin, it has become widely recognized that living things have undergone great change in the past and are still changing, and, moreover, that the manner and cause of the change is a subject fit for inquiry.

All men do not possess the same outlook on the question of the origin of living things. We cannot say that this or that outlook is the true one, and that all others must be forbidden.

In spite of much difference of opinion as to the cause and method of the process, there is a general agreement among biologists that animals and plants have arrived at their present condition through evolution. We will now consider the reasons for this agreement of opinion. The question may be examined from more than one point of view.

THE EVIDENCE AFFORDED BY COMPARISON.—It was explained in the last chapter, that the resemblances and differences between the various animal forms were not haphazard, but that they bore a relation to one another, so that the animals could be classified in an orderly manner in accordance with them. Every animal can be placed in a primary group, or phylum. A phylum may be divided into a few classes, each class into a number of orders, each order into several families, the families into genera, the genera into species. The species themselves are divisible.

The whole animal kingdom may therefore be compared to a tree—the phyla to the primary divisions of

the stem of the tree, the classes to the larger boughs, the orders to the branches, the families to the lesser branches, the genera to the twigs, and the species to the leaves. This arrangement is what we should expect if the various animals had been derived from one another by evolution. The study of animals is almost entirely a making of comparisons, an observation of resemblances and differences; our perception of these is much more acute when we are searching among mankind than among other living things. In our eyes no two men are exactly like one another, while superficially no two crows look different. With the help of this acute perception, which we all have when looking at ourselves, we know that men who are closely related by birth are usually more like one another than those who are distantly related. We apply this experience in a broad way to all living things, and assume that blood relationship, or, as it is also called, genetic relationship, between any two living things is directly proportional to the amount of resemblance which they exhibit. This is the principle on which our classification of organisms depends. In order to amplify this statement, we will look at the different stages in that process of classification which zoologists bring to bear upon the animal kingdom as a whole.

Some zoologists, usually styled Morphologists, make it their work to examine the main groups of animals, in order to find resemblances and differences between them. For example, they recognize that although the Insects,

Arachnids, and Crustacea are separate groups, owing to anatomical similarities within the groups and differences between them, yet there are certain main features common to all three, which cause them to be classed together as Arthropods. They recognize that the group of Arthropods is more like the group of the Annelids than either group is to the Molluscs; the student himself will recognize these things when he dissects the types. The Morphologist further divides the groups into subgroups. His task is a difficult one: he bases his conclusions chiefly on the internal structure of the adult animals and on their method of development. Other zoologists are called Systematists. They study the smaller and more numerous groups—the families, genera, and species. Their observations are made on the outward form of the animals, for, as regards internal anatomy, the members of those smaller groups are usually alike. But the method they apply is exactly the same in principle as that of the Morphologists; *they observe resemblances and differences*, and classify the animals in accordance with them. But the process of subdivision does not stop here, for species are divisible.

To show how far classification may be carried, the following case may be mentioned. An Indian gentleman who was well acquainted with many of the Asiatic races, met a stranger in London and addressed him as follows: "I have never seen or heard of you before, but I am sure you are a Kasmiri, and I think I know your father's name." He was right in both assertion and

assumption. This illustrates how far classification may be carried. The Kasmiri was accurately classed not only with his race, but with his father, and this result was arrived at in exactly the same way as the results of the Morphologist and the Systematist—*by the observation of resemblance*. In this case, the observer was not dealing with past history, and therefore, although his opinions were in the first place based upon the observation of resemblances, he was able, unlike the Systematist and Morphologist, to confirm them by an inquiry into the parentage of the man from Kashmir. The exact relation of the man to the other living beings which resembled him was therefore unmistakably known: assumed in the first place from resemblances and afterwards confirmed by inquiry. We assume that genetic relationship between living things is directly proportional to the resemblances which they exhibit. It is on this assumption that our methods of classification depend, but it is only when we examine the actual parentage of man or of captive animals *that we find the proof of the assumption*.

In studying comparative anatomy we examine animals and observe their resemblances and differences. This must be done carefully, for it is sometimes found that two animals which are superficially alike are in reality very different from one another, and the converse of this is true.

The student must distinguish between the two kinds of resemblances, the genetic and the non-genetic; it is usually easy to do so, but not always. The fact that

many vertebrate animals have two pairs of limbs each ending in five digits is considered to be due to community of descent, that is to say, the resemblance is genetic. Structures of this kind which occur among two or more groups, otherwise distinct, are said to be homologous with one another. The wings of a bird and of an insect are not homologous; there is no anatomical similarity between them: they are therefore said to be analogous. The wing of a bird is homologous with the fore limb of other vertebrates.

THE EVIDENCE AFFORDED BY FOSSILS.—Before examining this we must inquire a little into the teachings of geology. The history of man, as known from his written records, stretches backwards for less than ten thousand years; but geology teaches us that previous to this, and for many millions of years, the face of the earth was in many ways as we now know it—that is to say, there were areas of land and water on and in which animals and plants sustained themselves. But the relative distribution of the land and the water was not as at the present day, but changing again and again. The change, which was not necessarily continual in all parts of the earth's surface, was, for the most part, very slow. It was brought about by the gradual rising and sinking of different parts of the earth's surface at different times. Those parts which were raised became dry land, those which sank became covered with sea. Then, as now, water vapour arose from the sea, and passing over the face of the earth gave rain to it.

Much of the rain water became gathered into rivers, which carried mud and sand down to the sea, building up the bottom of it like a mud floor. The sea bottom by elevation became land, the mud and other material of which it was composed became hard rock; upon this the rain fell and the rivers flowed and carved out the valleys, leaving the thickness of the rocks exposed in hills and ridges. The hard parts, such as the shells and bones, of those animals which died in the ancient seas, are therefore preserved to this day as fossils embedded in rocks far removed from the seas of our time. Geologists can determine the relative ages of the rocks; they can say one rock is older than another because it lies underneath and was formed before it. It is clear that the study of fossils must afford direct evidence in the inquiry. If we wish to know whether a thing is changing or not, we must examine it at different times; if the change is slow we must examine it at long intervals. Fossils enable us to examine the succession of things which have lived in the past, at times separated by long intervals.

The study of fossils, or Palaeontology, as it is called, has taught us that many kinds of animals lived in the past which were unlike those living at the present day. Some of them were of gigantic size, but in their bony structure they resemble in a general way the living animals of to-day, so that it is possible to recognize one as an amphibian, another as a reptile, a third as a mammal. Some extinct animals are known which

resemble one group in some parts of their anatomy, and another group in other respects. For example, several are known which resemble mammals in some ways, although in most other respects they are reptiles. Certain extinct reptiles resemble birds in the formation of their skeleton; one of the most interesting fossils is the bird Archaeopteryx. This possessed feathered wings and was therefore a bird, but it also had conical teeth in the jaw and a long-jointed, bony tail; the wing was not like that of a modern bird, for it possessed two fingers with claws. In the teeth, tail, and in other respects it resembles a reptile. Unfortunately, the record of fossils is very imperfect. Thousands of animals must have lived for every one which has been preserved; and of those few which have been preserved, thousands must lie hidden within the rocks for every one which is brought to light.

If the whole series of animals which have lived in past years could be brought before us as evidence in the inquiry, it would be best to examine only those which were somewhat alike, and had followed one another in time, on a particular part of the earth's surface; any other method of examination would lead to confusion. Although the record of fossils as a whole is very imperfect, there are certain parts of it which are almost perfect, and furnish the strongest evidence of evolution which we possess. The case of the horse is the best example. Horses belong to a group of herbivorous mammals called the ungulates. In them

the weight of the body is supported by the ends of the digits which terminate the limbs. Most of the ungulates show a loss in the number of the digits, and of the bones which lie between the digits and the wrist or ankle-joints; but those that remain are lengthened and strengthened. These peculiarities are more marked in the horse (ass and zebra) than in any other members of the group, for the limbs of a horse each end in one digit only, and the joints which correspond to the wrist and ankle-joints of other mammals are raised well above the ground, and are called the knee and hock respectively. There is, in North America, a series of rocks the relative ages of which are clearly known from their relative positions; the most ancient rocks being, of course, the lowest, and the newer ones lying above them. These rocks are called the Tertiary series, the oldest of them is the Eocene, above that is the Miocene, and above that the Pliocene; of each of these divisions we may speak of a lower or older part and an upper or newer part. The highest, or Pliocene, rocks contain the bones of true horses, like those which are known to us at the present day; but the more ancient Miocene and Eocene rocks contain the bones of horse-like animals which resemble horses to a smaller and smaller extent as they are more and more ancient. The changes are shown on Plate XIV., which is copied from the lectures of the late Professor Huxley, who stated concerning it, "Professor Marsh's kindness has enabled

me to put before you a diagram, every figure in which is an actual representation of some specimen which is to be seen at Yale at this present time." The evidence in favour of evolution afforded by the extinct horses of America is, I think, the best available. It proves that a series of animals lived in succession, each member of which was slightly different from its predecessor. So far as our experience goes, animals are born from animals and not from inanimate things; it therefore seems most likely that these different kinds of horse-like creatures were born from one another. The facts themselves do not show how this occurred; how far the change was a very gradual one, so that parent and offspring were at no time distinctly unlike one another, or how far the change was sudden, so that on rare occasions it happened that parent and offspring were considerably unlike, are questions which cannot be solved by the study of fossils. But many other important things are shown by this study. The earliest fossils which are known to us show that the great groups of Invertebrates—the Molluscs, Echinoderms, Crustacea, Arachnids, and Insects—were as firmly established and as distinct from one another when the record commenced as they are to-day. Among these early invertebrates are certain species among the Molluscs and Brachiopods which scarcely differ from animals living to-day. Fossils afford little evidence to show how the great groups of the animal kingdom were established. But the record shows that, although fish

are, among the oldest fossil forms, the other groups of vertebrates, the amphibians, reptiles, and birds, did not appear until later; that the mammals appeared at a still later date than the others, and that among mammals, man himself was one of the last to appear. The geological history of man extends backwards for nearly a quarter of a million years.

THE EVIDENCE AFFORDED BY DEVELOPMENT.—Every living thing begins life as a single cell, which is usually formed by the union of two germ cells, one the product of a male parent, the other of a female parent. This initial cell, or zygote, becomes the offspring by segmentation and the various processes of development. The study of the development of animals is called embryology; it has shown us that the various stages in the development of the higher animals resemble in some ways the adult forms of lower animals, not in outward appearance, but in certain details of their structure; for example, it is known that in the embryos of some of the mammals - of the birds, reptiles, and amphibians—the throat is perforated by a number of slits through which the pharynx communicates with the outer world. These slits, which are exactly like the gill slits in the throat of a fish, become closed as development proceeds. This is merely a single instance of an occurrence the like of which has been seen in every part of the animal kingdom. An individual animal in its development passes through stages in which it partially resembles the adult form of simpler animals; from this

the assumption is made that the development of an individual is to some extent a repetition of its ancestry. It must be remembered, however, that certain animals pass through stages in their development which cannot possibly have occurred as adult stages in their ancestry, as, for example, the pupa stage of insects: also that certain stages which must, if the theory of evolution be true, have occurred in the ancestry of individuals, are not represented in their development. An example of this is offered by the fact that limbs are not found in the embryos of snakes. Although embryology is of great use in helping us to understand the relations of the great groups of the animal kingdom to one another, it does not seem to be a safe guide which will lead us to a complete understanding of the manner in which the great groups of the animal kingdom have arisen; indeed, there seems to be no safe guide to such very ancient history.

Circumstances which influence Evolution.—The factors which influence evolution may be described under three categories—Natural Selection, Isolation, and Segregation.

Natural Selection.—Natural selection is considered by some to be the essential cause of evolution. Others believe that it exerts an influence on evolution, but are of the opinion that the explanation of evolution lies in the origin of variation, the essential cause of which is far from being understood at present. As a simple example of the action of natural selection, we will consider that of a herbivorous animal which has the misfortune to

be born without the sense of hearing. Such an animal if born in captivity could sustain itself easily: it could produce offspring, some or all of which would probably be deaf; but in a state of nature, such an abnormal creature would not be fully warned of the approach of danger, and would soon fall a prey to some carnivorous enemy. Even if it succeeded in leaving offspring, those which were deaf would be under the same special risks. We may say, therefore, that the deafness would soon be stamped out by natural selection.

The term "natural selection" originated in the following manner. There are many domestic varieties of animals and birds which are as distinct from one another in appearance as species in nature. It is the custom to speak of these domestic varieties as being produced by artificial selection, because the fancier, or man who produces them, selects for breeding those individuals which possess any peculiar or useful quality. It is plain, however, that the fancier does not actually create anything by artificial selection, he can only choose from the variations which appear. The power of artificial selection to produce domestic varieties, gave birth to the idea that there was a similar power in nature, which produced the natural species. This power is therefore called Natural Selection. Under nature, animals compete with one another, and those which are best suited to the conditions of life survive, *i.e.* they are naturally selected to survive. Many die in the stress of competition without leaving offspring. It is

well known that there is a great mortality among the immature of many species; the rate of mortality is, however, very different in the various species. The tape-worm and many fish produce millions of eggs; their progeny are liable to many dangers. In any species which remains stationary in numbers, the place of one mature animal which dies is taken by one only of the next generation; how great, then, must be the mortality among the young of animals such as fish! Natural selection has then an influence in nature, destroying those animals which are less suited to the conditions of life than others, and with them their germ cells, which would give rise to further unsuitable offspring. The expression "suited to the conditions of life" is merely a relative term. We cannot say that an animal is perfectly or imperfectly suited to any conditions, but only that it is more or less suited than other animals. In considering how any kind of animal multiplies, we must regard two things — the rate at which animals of that kind are born, and the rate at which they meet death while immature. They are saved from untimely death by their various attributes: their senses, their methods of defence, the mechanisms by which they obtain food. It is clear that no amount of perfection in these respects will cause a race to increase, if the rate at which its members are produced is low. The fertility of any race of living things is therefore of more importance to it than any other attribute. In considering the question as to which of

two competing individuals or races will succeed, we must consider all their attributes; one race or individual will possess certain advantages, another may possess the same advantages in different measure and perhaps special advantages of its own. The sum total of the advantages of the one is weighed against that of the other. Natural selection will be considered later on as an explanation of adaptation.

THE INFLUENCE OF ISOLATION.—It sometimes happens that among a common and widely distributed species, certain individuals which are endowed with peculiarities not possessed by the majority, are born from time to time. These abnormal individuals, or sports as they are called, are in the first place the offspring of normal parents, and mate perhaps with normal individuals, and although they may give rise to abnormal offspring, their kind rarely meets with much success, because they are so few among the normal multitude. The abnormal strain dies out unless it possesses a very decisive advantage over the normal. But the case may be otherwise when a wide-spread species gives off by migration a number of small separate groups, which come to be separated by natural barriers, such as mountain chains or the sea. In a small community, an abnormal strain has a better chance of becoming dominant. It is well known that isolated areas are often inhabited by their own particular kinds of animals, the like of which are not found in any other place. This fact is well illustrated by the rats of India.

We cannot with certainty distinguish the house rats of one town from those of another, if the towns from which they are taken are on the plains of India. This is true even when the towns are situated many hundreds of miles apart. The rats in one town often show considerable differences among themselves, but distinctive peculiarities are rarely found among the rats of any one town or district. But it is otherwise with the house rats which live in towns situated among the Himalayas. Rats taken from Katmandu, Darjiling, Simla, or Kashmir can be distinguished from one another with confidence; for the rats of each place have their own special peculiarities by which they can be recognized. Now, these peculiarities or marks are often of the same kind as those met with on the sports which occur among the mixed lowland rats. For example, the rats of Darjiling have white feet with black soles; by this, and other features, we can recognize them. Lowland rats have brown feet with greyish soles; but sometimes we find a lowland rat with white feet, not necessarily associated with black soles, and not always wholly white, sometimes the whiteness only affects the digits, or even only the ends of them; but there is certainly a tendency towards the acquisition of white feet in some few of the lowland rats. Another case illustrates the same thing. There is an isolated race of rats in the Madras hills which can be distinguished by the fact that the last part of the tail is white. There are other races showing the same peculiarity in the islands of the Eastern

Archipelago. These races are distinct from one another, for they show certain other peculiarities, and each is in an isolated position. Now, the same peculiarity a tail with a white end—may sometimes occur on individual rats found in Indian lowland towns, and more than one such sport may be found in company; for example, two may be caught together in the same trap. We know, therefore, that extensive and continuous land areas may be occupied by a large mixed species of animals, while neighbouring isolated areas may be occupied by small pure races which are closely allied to the large species, and that the peculiarities which are the distinguishing marks of the small races may occur occasionally in single sports, or in small groups among the large species.

These remarks do not apply to all characters, for all hill rats have long, plentiful fur, while lowland rats have more scanty fur.

Isolation has therefore an influence in the formation and maintenance of races. Indeed, it is difficult to understand how a pure race can arise in the midst of a wide-spread, mingling race, unless it is isolated in some way. Isolation may be brought about in another way. Mutual sterility is a more effectual means of isolation between two animals than any natural barrier, for it is impassable. If among a common species of animals, a few abnormal individuals were to appear, perhaps as the offspring of the same pair of parents, and if these were to be very fertile with one another but sterile

with all others, their descendants would preserve their special identity as safely as though they were alone on an island. There is at present no direct evidence that species arise in this way, but the supposition that they do involves no impossibility,—for we know, firstly, that animals are sometimes born which are considerably unlike their parents; secondly, that sterility affects certain members of a species: an animal may be sterile with one mate which is not in itself sterile, and yet be quite fertile with another; thirdly, we know that inbreeding is not always detrimental for a few individuals; for example, rabbits can stock a continent with their kind.

Segregation and Aggregation.—These factors have not been the subjects of much experiment, but are chiefly known from general experience. As an example of what is meant by segregation we will consider the following case. Deer and other animals are often kept in parks running free and uncontrolled; it sometimes happens that different domestic stocks are slightly different from one another. A herd raised in a certain place may be noticeably lighter in colour than a herd raised elsewhere. If now two herds which are very slightly dissimilar be introduced together into a park which is new to both, they will soon part company and roam independently. It may be said that this is only what we should expect, which is another way of saying that the occurrence agrees with our common experience. If men of two separate races be placed

in an enclosure, as prisoners of war for example, they would form two groups. We may say that they would do this because of their reasoning powers and the diversity of their language or dialect, but these men would only be acting in exactly the same way as the deer, which are not provided with anything recognizably like our own reasoning power and language.

It seems, therefore, to be a wide principle in nature that those animals which are unlike one another are segregative, and those which are very alike are aggregative. It seems generally true that the sympathy and antipathy which men experience in their relations with one another, are based on their mental resemblance and differences. This principle cannot, of course, be regarded as a rigid law, for animals which are very unlike are not necessarily repulsive to one another.

The question of selective mating is one with the question of aggregation. Very little is known about selective mating except that it is not a haphazard process, but is guided by resemblances. Animals usually find their mates among their own race; but a race is divisible, and it is probable that the divergent members of a race which resemble one another in their divergent characters are especially likely to select one another for breeding. In the future we shall no doubt learn more about such matters by experiment.

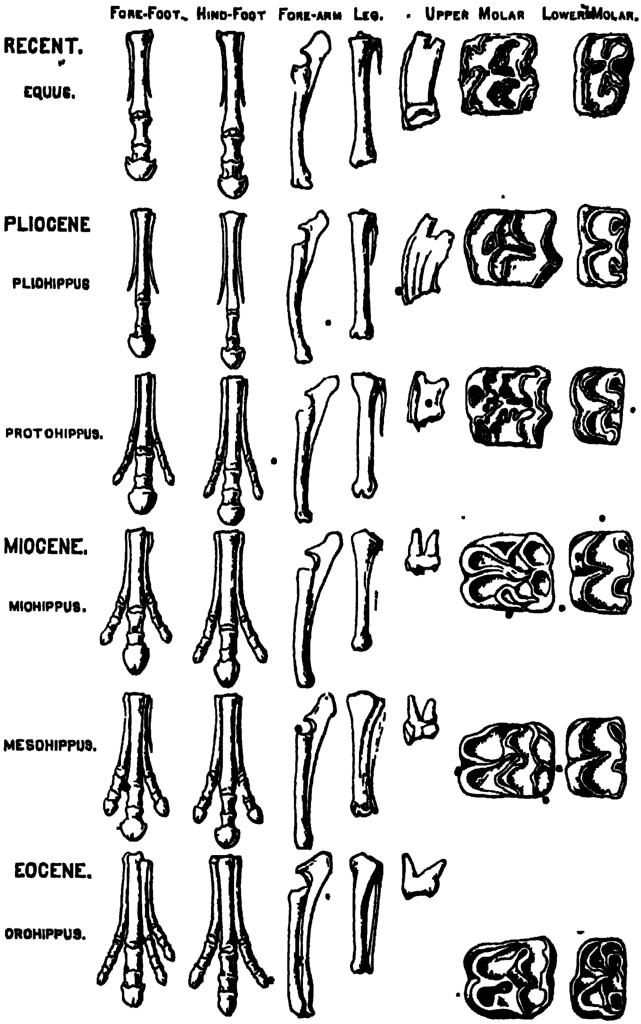

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PLATE XIV

ADAPTATION

All living things are suited or adapted in their form and activity to their surroundings. If they were not so they could not live; a bird cannot live permanently in the water, a fish cannot live out of it. We can see adaptation among living things in two separate cases. The first of these may be called individual, or acquired, adaptation: when the circumstances which surround any individual living thing become changed, that individual may change in form or attributes in such a way that it becomes suited to the new circumstances. The second class of adaptation may be called inherited adaptation. We see it in all organisms which are already adapted at birth to the life they must lead.

It is necessary to draw a line between these two classes of adaptation. I will quote words written this year. "In the present position of biological science evidence of adaptation is commonly accepted as presumptive evidence of the action of natural selection." If this is the general opinion of biologists at the present day, it is necessary to draw a distinction between acquired adaptation and inherited adaptation, for we know that acquired adaptation cannot be explained by natural selection, because an individual organism may become adapted at once to circumstances which are occurring for the first time. Inherited adaptation can alone be explained by the action of natural selection.

Acquired Adaptation. The following examples will

show what is meant by "acquired adaptation." They are examples of changes which take place in an organism in response to a change in its circumstances, and are such that they are for the benefit of the organism to enable it to withstand the new conditions. Such changes may be temporary or permanent during the life of the individual.

1. At the commencement of the cold season, the hairs in a horse's skin become longer and more plentiful. When the warm weather returns the hair falls out in large quantities. This is probably true of many other animals, but it is most noticeable in the horse.

2. When the skin covering a man's shoulder, or the neck of an ox, is subjected to frequent pressure and friction in carrying burdens, it becomes very thick, otherwise the skin of these parts would not save the underlying tissues from the effects of the pressure and friction.

3. If the stems of some of a number of like seedling plants are subjected to tension by a string to which increasing weights are attached, it will be found that they break on the application of a certain strain. If now the remainder of the seedlings be subjected to a a tension which is somewhat less than the breaking strain for a few days, it will be found that they have undergone a change, and have become able to withstand a tension much greater than the normal breaking strain.

If a man be in the habit of taking drugs, such as morphia, alcohol, or arsenic, in small and increasing doses, it will be found that he becomes changed, so that he can withstand doses of those drugs which would usually be fatal to other men.

5. If an animal be treated with small and increasing doses of an albuminoid poison, such as snake venom, a bacterial toxin, or the vegetable poisons ricin and abrin, it will be found that he can soon withstand a fatal dose of those poisons. These cases seem essentially like the last, but there is this difference between the two. Soon after the injection of an albuminoid poison, a substance known as an antibody will appear in the blood of the animal. An antibody will neutralize or kill the particular poison which called it forth, just as an alkali will neutralize an acid. It is only in the case of albuminoid poisons that antibodies are formed; antimorphine or antiarsenic are not found in the blood of an animal which has been treated with morphine or arsenic. The results which follow the injection of a chemical poison are therefore different in their mode of occurrence from those which follow an injection of an albuminoid poison; but the cases are similar in effect in that the change which is wrought in the organism is in the direction of benefit to it. It seems that there must be some essential resemblance in the two cases which we do not understand at present.

6. The process of healing may be considered as a necessary or adaptive change which takes place in an

organism in response to an injury. Healing is brought about by regeneration, by the formation of new cells which grow out from and become arranged in the same way as the other cells of the body, as epithelia, as blood-vessels, or nerve fibres; in many of the lower animals this process is much more complete than in the mammals, so that the regenerated cells become arranged with great precision, and produce a new organ in every way like the old one which it has replaced. For example, if a lizard's tail be broken off, it becomes replaced by a new one in a few weeks. The process can often be watched in wall lizards in India. It is plain that lizards are much more likely to lose their tails by accident than other animals, and that they can regenerate their tails much more easily than other animals.

7. The behaviour of animals becomes altered in accordance with changing circumstances. If a pair of pigeons be placed in a very large cage they will produce young time after time. If now the same pair be transferred to a very small cage they will produce no young. At present there seems to be no explanation of this, except that it is better for the pigeons to remain as two in a small cage.

INHERITED ADAPTATION.—Cases of inherited adaptation are so numerous that they need not be mentioned, for it is obvious that all individual organisms, in virtue of that which they inherit from their parents, are more or less adapted to their surroundings. The most

striking examples of this adaptation are afforded by the protective resemblances of certain animals, especially insects and marine creatures, which in shape and colour resemble their surroundings so closely that they are naturally concealed either from their enemies or from their prey. Other wonderful examples are seen in plants, especially orchids, in which the flower is remarkably adapted to be pollinated by insects.

The explanation of inherited adaptation is as follows. It is assumed that living things tend to vary or differ from one another in all directions. When any change takes place in the circumstances of a population, since the members are varying in all directions, some of them must be adapted to the new circumstances. These adapted ones will live more easily than the others, they and their descendants, which are like them, will be preserved; the majority, which are not adapted to the new conditions, being at a disadvantage, will dwindle and die out. If this is a true explanation, a race can only change when its circumstances change. The theory is directed to explain adaptation, for it supposes that variation is no more likely to occur in the direction of adaptation than in an opposite direction, or thousands of other directions; but because it takes place in many directions, some few animals must be adapted to almost any circumstances which may arise, and it is those few which are preserved by natural selection, hence living things are adapted. The question cannot be further discussed here; any one who is

interested in biology should read the works of Darwin himself.

It is generally believed by biologists that the changes which take place in any individual during its life are not effective in producing change in the sequence of individuals which replace one another by death and birth. The important question, Are acquired characters hereditary? is usually answered in the negative. This is in accordance with general experience, for although age in parents often leads to wisdom and experience, younger sons are not as a rule wiser and more experienced than their elder brothers. At any rate, it has not yet been shown that the acquirements of individuals are added through their offspring to the heritage of the race to which they belong, and we may be sure that any important change which occurs in a race takes place by the substitution of offspring for parent, when they are different from one another. At present there is no proof that the changes which take place in the substitution of offspring for parent are particularly in the direction of adaptation; on the contrary, we know for certain that such changes are sometimes in the opposite direction, as when the child of healthy parents is malformed, and we know also that many of the changes appear to be indifferent, *i.e.* neither adaptive nor unadaptive. We do not yet know whether a population, around which circumstances are changing so that the new conditions are unsuitable, can become changed by the production of individuals which are suited to the new conditions; but

we must remember that if such adaptive changes, which are directly called out by the needs of a population, actually occur, it is not in itself more wonderful than our experience of individual adaptation, by which we know that changes may often occur in an individual in direct response to its needs.

CHAPTER X

VARIATION

We know that no two living things are exactly alike, though, as a rule, the members of a race or kind of organism which live and breed together are very like one another. The term "variation" is difficult to define; it is used in a general way to express the differences which we see when we compare, one with another, a large number of the members of a race. We may also apply the term to those differences which occur between a parent and its offspring. It may seem that the second definition is included in the first, for it is often thought that a parent and its offspring must always be of the same kind. It is, however, not always true that a parent and its offspring must be of the same kind. The following is a well-known exception. It has happened, on more than one occasion, in different parts of the world that horned animals, both cattle and sheep, have produced hornless offspring, and that these latter have in their turn produced hornless progeny, even when paired with horned mates. In the ordinary sense of the word, horned and hornless animals are of different races. We must therefore dismiss the

assumption that a parent and its offspring must always be of same kind.

Variation may be studied in two ways, either by examining and comparing large numbers of individuals which are found living and breeding together and appear to be of one race, or by the more exact method of breeding experiments, in which parent and offspring can be compared and their differences observed. The first method is easy, but it is unsatisfactory in practice, for when abnormal individuals which are unlike the majority are met with among the race examined, they may be considered by the observer to be interlopers of another race, and in making his decision as to their nature there is nothing whatever to guide him. No such objection can be raised against the study of variation by breeding experiments in which the parentage of all the organisms, normal and abnormal, is known. Unfortunately, prolonged breeding experiments are tedious and difficult. It sometimes happens that naturalists meet with parent animals together with several of their offspring which may be captured and compared; this is a third method of studying the question which is as certain as the second method, though more limited.

If we are to study animal variation in a general way, by examining all those differences which can be seen among the members of a race, we must first inquire briefly into what is called chance. If a coin be spun in the air and allowed to fall, it will lie with either the

"head" or the "tail" side uppermost. There seems to be no reason why it should fall more often in one position than in the other. If the coin be tossed one thousand times, it will fall nearly five hundred times in one way and nearly five hundred times in the other way, otherwise it has not been falling by chance. If now two coins be tossed together they will be found lying so that both heads, 2H, or both tails, 2T, or one of each, HT, are lying uppermost; but it is more likely by twice that HT will appear than either 2H or 2T, while it is equally likely that 2H and 2T will appear. When two coins are tossed the forces which determine the manner of falling act equally upon four things, 2H and 2T, only two of which fall uppermost at one time. A particular pair of the four is not more likely to appear uppermost than any other pair, consequently the combination HT must appear twice as often as either of the others. If this is not obvious to the student, let him consider the case when one coin is silver and the other copper. There will then be four separate things, one copper head and tail (CH, CT), one silver head and tail (SH, ST), for the forces to choose from. On tossing, the four different combinations SH—CH, CT—ST, ST—CH, SH—CT are all equally likely to appear uppermost. But if we disregard the quality of the metal the result is the same as before, HT occurs twice as often as either of the others.

By simple calculation, therefore, we can find the result of tossing two coins on many occasions without performing the experiment. By further calculation a

mathematician can find the result of tossing ten coins a large number of times, that is to say, the result when twenty things of two kinds (10H, 10T) are taken by chance ten at a time on a thousand or more occasions. It is plain that in such a case the combination 5H—5T is more likely to appear than any other, and that 10H or 10T must not only be very rare, but must be equally rare. The result as calculated by a mathematician is shown below side by side with the result of an actual experiment in which ten new rupees were tossed 1024 times.

Head.	Tail.	Calculation.	Experiment.
10	0	1	2
9	1	10	10
8	2	45	61
7	3	120	140
6	4	210	105
5	5	252	223
4	6	210	187
3	7	120	148
2	8	45	74
1	9	10	20
0	10	1	4
		1024	1024

It is interesting to compare the results of the experiment with the result of the calculation. They are nearly but not quite alike; this is because the coins fell nearly but not quite by chance. Some influence was at work which prevented them falling entirely by chance. It will be noticed that by calculation the combinations 6H—4T and 6T—4H should occur equally often, the same

is true of the combinations 7H – 3T and 7T—3H, and of the others when taken in pairs; but in the experiment, the combinations 6T—4H and 7T—3H, etc., occur somewhat more often than they ought to. This is probably because the figure on the head side of the coins, which were new ones, was heavier than that on the reverse, consequently it was slightly more likely that the tail side should appear uppermost. The result of such experiments are best displayed to the eye by means of diagrams, in which numbers are represented by lines containing as many units of length. The result of the calculation and of the experiment are shown side by side with the diagrams on Plate XV. I think that this illustrates what is meant by the saying that certain events happen by chance; in the experiment the coins fell nearly but not quite by chance.

We may now pass to the question of variation. The differences which occur among the members of a race of living things often occur as though by chance, but by no means always so. This enables us to recognize two kinds of variation: the one which occurs as though by chance is called fluctuating variation; the other is called mutation, for it is believed that only this kind of variation is effectual in the production of new species. This method of analyzing variation, which was proposed by De Vries, has been accepted by many biologists, but not as yet by all.

Fluctuating Variation.—If the height of a large number of men of one race be measured, it will be found

that the measurements can be naturally arranged much the same way as the results of the coin-tossing. In the case of the ten coins it was found that the combination 5T –5H occurred more frequently than any other; it will also be found if the measurements of the men are examined, that one particular height, sixty-nine inches for Englishmen, occurs more frequently than any other. This particular measurement is called the mean height of the race. It will be found that the frequency of occurrence of the other measurements becomes less and less as the measurements become further and further removed from the mean, both above and below it. The similarity of the results of the coin tossing and of the measurements becomes apparent when both are arranged in a diagram, in which the frequencies are represented by lines of proportional length. When large numbers of organisms of any race are measured as to any particular feature, it will usually be found that the measurements can be arranged symmetrically about a mean, just as in the case of the statures of men. Normal variation of this kind occurs in every detail of every race of living things. In man it occurs as regards height, weight, length of span, length of cubit, or any attribute which can be measured. It may interest the student to know that it is approximately true of the number of marks obtained by candidates in examination, which may be taken as a rough estimate of mental capacity. Examiners find that if their question papers are well adapted to the powers of the candidates, a majority of them will obtain about

50 per cent. of the full marks, a smaller number will obtain about 75 per cent., and an equally small number will obtain about 25 per cent. When the majority, that is to say, the average students, obtain about half marks, the line which separates passed from failed must be drawn at about 30 per cent. or 70 per cent. of the full marks, and never at 50 per cent. It cannot be justly drawn through the middle of the average men, but must be drawn either above or below them, so that they are rejected or passed as a whole. This illustration is not meant merely to amuse the student, but to point out how a knowledge of variation may be useful in daily life.

Let us now consider the question as to whether fluctuating variation plays an important part in the production of new species. There is much difference of opinion among Biologists on this subject. The question can be illustrated by the following imaginary example. Let us suppose that upon a stable race of men, the mean height of which is sixty-nine inches, an edict is enforced forbidding all persons under that height

PLATE XV.

A. Diagram showing the expected result of tossing ten coins on 1024 occasions, as calculated by a mathematician (see text).
B. Diagram showing the actual results obtained by trial; ten newly minted rupees were used for the experiment.
C. Diagram showing the weights of a thousand mature rats which were caught in Poona. The figures on the base line show the weights of the rats in grammes. The upright lines show the numbers of rats of each weight, and must be referred to the column of figures on the left; the lengths of the uprights are proportional to the numbers shown there.
D. A diagram similar to C, but constructed from more numerous and more accurate measurements (stature in inches of 4426 Englishmen, recorded by the Cambridge Anthropometric Society).

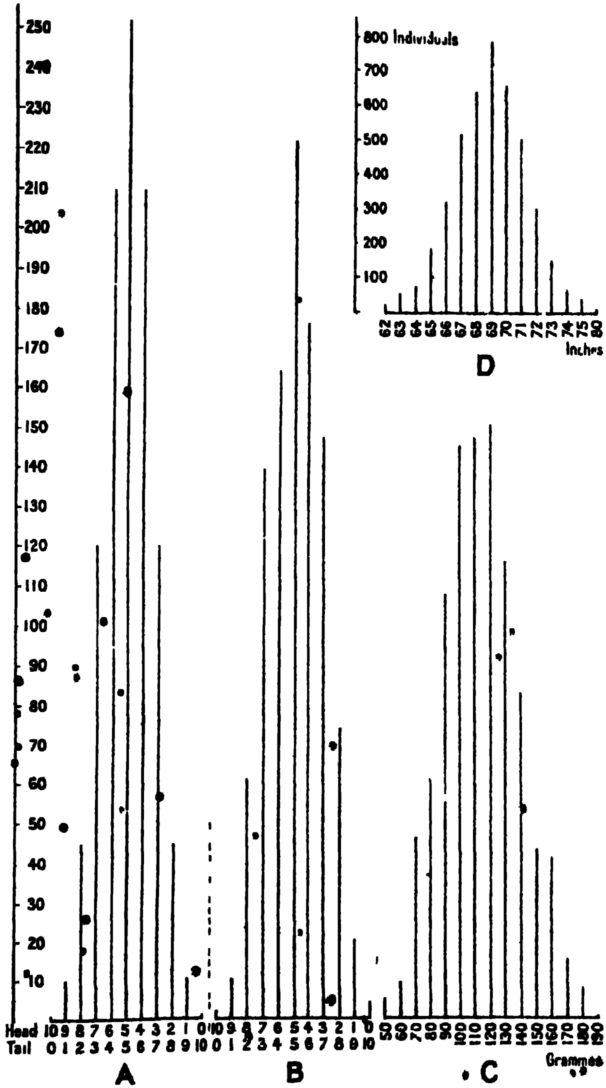


PLATE XV.

from becoming parents. There is no doubt that in two or three generations the mean height of the race as a whole would be raised. If now the edict, after being in force for several generations, were to be removed, what *would* happen? Most biologists agree that the mean height of the race would not remain at the new level, but would sink back to the old one after a few more generations. The question now arises as to whether it would be possible by any means of selection to produce a permanent or stable race of tall men. The opinion is held that it would be possible, not by indiscriminate selection of the tall, but by selecting special individuals which are not only tall themselves, but are endowed with a special power of procreating tall offspring; these individuals are mutations as regards tallness which may be mingled with the fluctuating majority. According to this view two tall men of equal height seventy-two inches--but different parentage may, as regards their tallness, be essentially different from one another: the one may belong to the common line of the race, the variation which he shows being a fluctuating variation,—his offspring will not be of unusual height; but the other may belong to a different line, the mean height of which is, perhaps, seventy-three inches—this man will have the power of procreating tall offspring.

We can understand to some extent why an attribute should fluctuate as though by chance. If it were possible to ascertain the weight of food which passes the

lips of every man in a large town during a certain period of time, there is little doubt but that we should be able to arrange the many values in a rough symmetry on either side of a mean, much in the same way as the results of the coin tossing were arranged. Food is merely one of a large number of things which come to an organism from without and influence it: the term "food" itself includes many different kinds of substance. It is probable that every force or substance which influences growing organisms can, as regards the various degrees in which it influences them individually, be arranged in the same way as the amounts of food per man could be arranged. Hence we can understand why the effects of the influences should be distributed in a similar manner.

MUTATION.—The opinion is held that fluctuating variation is a constant phenomenon which is to be seen in every organism and in every part of it, and that it plays no part in the production of new species. Mutation is regarded as a less constant but by no means rare occurrence, which may be effectual in establishing new species. The question as to whether or not a mutation shall establish a new race is decided by its relative fitness in competition with those already established. The term "mutation" was introduced by De Vries, who found that on sowing the seed of a certain plant, Oenothera Lamarckiana, the seedlings which were raised were not of one kind, but of several kinds. Oenothera possesses self-fertilizing flowers.

During eight years about 50,000 plants were raised, all from the self-fertilized seed of O. Lamarckiana; about 800 of these were unlike the parent form. Among these unlike ones were seven different kinds; some kinds appeared only once or twice, others were delicate and difficult to raise, but at least three kinds appeared on many occasions, and were strong and hardy. The kind named Oblongata appeared no less than 350 times; in every case, be it remembered, from the seed of self-fertilized O. Lamarckiana. These special kinds were called mutations and regarded as new species, for it was found, when their seed was sown, that the offspring of each came true to its own kind. This is regarded as an example of the way in which new species arise. Among a race showing fluctuating variation a few individuals arise, which possess a character or characters not possessed by their parents, or by the majority of the race, and these few will produce descendants like themselves, perhaps in such large numbers finally that a new race becomes established. If new species arise in this way other similar cases will doubtless be observed in the future.

Although the truth of this theory is as yet undecided, there is no doubt that by assuming it to be true we can explain certain facts in the distribution of the varieties of animals. The recent campaign against rats, which was undertaken because of plague in India, disclosed certain facts in the distribution of these animals which can be explained by this theory. The

common rats of India are usually of a dull brown colour, but in some places groups of rats are found in which the fur of the ventral surface is pure white. Rats of this kind are not found in one particular area, but occur here and there throughout the whole country. In the Punjaub, out of sixty-two villages in which many rats were caught, three contained these white-bellied ones. Again at Poona, where 40,000 common brown rats were killed, twenty white-bellied ones were caught in a few adjacent houses in the heart of the city. Rats of a black colour occur in similar isolated groups in certain places, although they are less common than the white-bellied ones. Rats in which the tail is partially white, and others which are marked with a white line on the breast, occur similarly in isolated groups. These facts are readily explained on the supposition that the germ cells of the common brown rats, although producers of brown rats as a rule, occasionally give rise to abnormal forms which are of definite kinds, the same kind appearing in widely separate places; in other words, the facts can be explained on the assumption that the gametes of the brown rats are behaving in the same way as the gametes of O. Lamarckiana.

It has long been known that parent animals may give rise to offspring which are distinctly unlike their parents, and that these offspring may at once breed true to their own kind. I will quote a passage from a well-known book: "In Paraguay, during the last

century (1770), a bull was born without horns, although his ancestry was well provided with these appendages, and his progeny was also hornless, although at first he was mated with horned cows. If the horned and the hornless were met in fossil state, we would certainly wonder at not finding specimens provided with semi-degenerate horns, and representing the link between both, and if we were told that the hornless variety may have arisen suddenly, we should not believe it and we should be wrong. In South America, also, between the sixteenth and eighteenth centuries the Niata breed of oxen sprang into life, and this breed of bull-dog oxen has thriven and become a new race. So in the San Paulo provinces of Brazil, a new breed of oxen suddenly appeared which was provided with truly enormous horns, the breed of franqueiros, as they are called. The mauchamp breed of sheep owes its origin to a single lamb that was born in 1828 from merino parents, but whose wool, instead of being curly like that of its parents, remained quite smooth. This sudden variation is often met with, and in France has been noticed in different herds" (De Varigny).

Other cases similar to the above are known. Among them we may mention the case of the black-backed peacock, examples of which may be seen at the Zoological Gardens in Calcutta. The black-backed peacock is like the common peacock except that it is somewhat smaller, and the back and shoulders are black and glossy. It appears occasionally among flocks of peafowl both in

the jungle and in captivity. We may make four statements about the black-backed peacocks. They are, in the first place, the offspring of common peafowl. They produce offspring of their own kind. They appear independently in widely separate places; for example, both in India and in Europe. Peacocks which are intermediate in colour between the two kinds are rarely if ever met with. I do not think that these statements have ever been proved incorrect. We therefore know that a new race of organisms may appear at a step, that is to say, the whole difference which separates two races may appear in the first place between parent and offspring. If the black-backed peacock were to be sterile when mated with the common kind, but fertile with its own kind, we should know the actual origin of at least one species.

The difference between the two varieties of peacocks is a good example of a mutation, for the difference is uncommonly wide, and very visible to our eyes. On the other hand, there seems to be no limit to the narrowness of the heritable differences between a parent and its offspring. But wide or narrow it is a fair assumption that the differences are passed from parents to offspring in the same manner, which will be described in the next chapter.

CAUSES OF VARIATION. The theory of the origin of species by mutation does not deal with the cause of the origin, but describes the manner in which new species arise. It is most important that the manner in

which events occur should be clearly understood before we commence to search for the cause of the events. The causes of variation are in the main unknown, and will probably remain so until we know something of the real nature of living matter.

Although the question does not appertain to biology in particular, it is well to consider what we mean by a cause. Many of the occurrences which we see are not single or isolated, but are preceded and succeeded by others. Many occurrences which appear at first sight to be single or spontaneous prove on examination to be merely part of a sequence of occurrences. We therefore assume that every event has a precedent occurrence (or cause, as it is called), although often we can neither see nor understand it. When we cannot understand the cause of an event we confess, or perhaps hide our ignorance, by applying a term to the unknown cause; for example, we do not know why bodies fall to the ground—we express the fact by saying that it is due to gravity. Again, we do not know why a horned creature should give birth to hornless offspring; we say that such an event is spontaneous, but we believe that such an event has a cause, although we are quite ignorant of it. It is well to keep in mind—

1. That events always occur in sequence, the cause of an event is merely the event or events which precede it.

2. Although it is necessary to apply terms in order

to express unknown causes, we must keep clearly in mind when causes are unknown.

3. When we know the cause of an event we can often control that event. We search for causes in order to control events.

Although we are for the most part in ignorance of the causes of variation, there are several well-known cases of a species changing in an orderly manner in response to some change in its surroundings, that is to say, whenever the particular condition is brought to bear on the particular species the same change will take place in that species. The following examples are among the best known of these.

1. Plants which grow on mountains at a great altitude are dwarfed and compact; they have greener leaves and brighter flowers than plants of the same species which grow in the lowlands. If seeds from lowland plants be sown upon the mountains, the plants which spring from them are of the dwarfed type. If a single plant be divided, and one half be planted on the mountain and the other half be set in the plain, the first will become dwarfed and bright coloured, the second will be taller, and its flowers will be less bright.

2. There is a small shrimp-like Crustacean called Artemia which lives in brine pools. It occurs in two forms, according as the amount of salt in the water of its abode is small or great. When Artemia is bred in a salt solution of specific gravity 1·02 the tail is of a certain size and shape, it is lobed and

provided with bristles; but when the animal is bred in salt water of specific gravity 1·2, the tail becomes smaller and loses the lobes and many of the bristles. The change takes place in a progressive manner if the amount of the salt be gradually changed

3. There are certain flat fish in the sea which have the peculiar habit of lying upon the bottom for short periods of time; in swimming they glide through the water in a horizontal position, not in the vertical position commonly assumed by fish. These fish, which are known as the Pleuronectidae, are white on that side which is not exposed to the light; if they be kept for some months in a glass-bottomed aquarium which is illuminated by mirrors from below, the white lower surface of the fish becomes pigmented in the same manner, though not to the same extent, as the upper surface. Other cases similar to the above are known.

Such changes are believed to be the result of special conditions acting upon each organism as it grows. The gametes of both types of Artemia, for example, are assumed to be alike at the time of their formation; however long the two types may have been living separately in salt water of different strengths, the change which determines the different kinds comes upon the animals as they grow. Changes of this kind are not inherited in any degree whatever. This is the opinion of most biologists at present, and it has not yet been shown that this opinion is incorrect.

Little can be said at present as to the causes of mutations which depend on gametic factors and are inherited. Let us consider the case of a hornless cow, or of a black-backed peacock, which are born from ordinary parents Such unusual events are known to occur independently in separate places. From a scientific point of view, we must assume that in each case the change is due to a particular external condition, which has influenced the germ cells of the animals in the same way on each occasion. We must also assume that each organism is specially liable to be influenced in its own particular direction. In other words, there is a relation between the nature of an organism and the nature of the conditions which surround it; so that if we could discover the conditions in any case, we would be able to bring about the change in the species at will. Such discoveries belong to the future, and no one can say how distant that future may be.

CHAPTER XI

HEREDITY—THE DISCOVERY MADE BY MENDEL

THE term "heredity" is indefinite. It is used in the following way: We say that an offspring resembles its parent because of heredity, or that an offspring inherits the quality of its parents. The quality which is transmitted from parents to offspring is sometimes called the heritage; the nature of the heritage and the manner in which it is transmitted are the subjects of the study of heredity. In the first place, the heritage is considered not as one thing, but as a combination of many things called characters, which are handed from parents to offspring as separate units; for example, a man's stature, the pigment in his eyes, and the quality of his hair are regarded as separate characters. Most organisms arise from the union of two gametes, one of which is contributed by either parent. Parents which come together for breeding are not wholly alike; as regards most of their characters they are alike, but either parent may possess one or more extra character units which are not present in the other. If we examine the offspring of unlike parents, we may find that some of them possess the extra characters of the one parent.

while others possess those of the other. The manner in which the characters of two unlike parent organisms are distributed among their descendants was discovered by Gregor Mendel in the year 1865, during some experiments on the cross-fertilization of plants; but the importance of the discovery was overlooked until 1900, since when it has become widely known and extended.

In science it is often necessary to make use of hypotheses. For example, chemists have propounded the theory that all matter is composed of units or atoms, which are of different kinds, and combine together in a definite manner to form the many kinds of material which we know. Although no one has seen these atoms, it is certain that by assuming their existence the science of chemistry has been much advanced, and it is equally certain that owing to this advancement man has acquired a considerable control over the material world.

It has also become necessary to make use of hypotheses in biology, and to assume the existence of certain units, or factors, as they are called, which lie in the gametes of all organisms, and determine the characters of the offspring which arises from the gametes. According to this theory, the whole nature of any organism is predetermined at the time of the formation of its parents' gametes, and corresponds to the number and kinds of factors which pass into the gametes at the time when they become distinct from the soma or body of the parent, and is finally determined when the two gametes meet to form the zygote from which the organism arises.

Our knowledge of characters and factors is in an early stage, but it seems that eventually we shall be able to classify them; for although each character is a different thing, some are more like one another than others. Let us consider the following cases. A number of plants are found growing together in a certain place, they closely resemble one another, except that a few of them have hairy stems and leaves, while most of them are quite smooth. In this case a few plants possess the quality of hairiness, a definite and tangible character which is not possessed in any degree by the majority of the plants. It may seem that such a case provides us with a clear idea of a character; but such an idea is too exclusive, as the following case will show. Two animals or plants may resemble one another very closely except as regards their total size, or as regards the size of some particular part of them, or in the degree of an attribute, such as pigmentation. Therefore, quantitative differences are also to be regarded as characters, determined by factors which lie in the gametes. The colours of animals afford good examples of factors. An albino animal, which has no pigment in any part of its body, is devoid of a factor for pigment. As regards colour, some animals appear in several states. A common example of such an animal is the horse. Many terms are used to describe the colour of horses—chestnut, bay, black, etc.—but two persons who are acquainted with the terms in use will rarely disagree over the application of a term

in any particular case. Each of these several coloured states is not necessarily the result of a separate factor, each different from the other, and each an addition of 1 to the Albino state, which may, as regards colour, be reckoned as 0, but of the several colour varieties which are apparent to our eyes—one may be due to a factor, A; a second to a combination of factors, A + B; a third to a combination, A + B + C.

If we leave the question of the kind of pigment, and regard only the distribution of the pigment, we see characters which seem, as a class, to be somewhat different from those we have been considering. Horses of all colours are liable to show a white patch on the forehead. This may be continuous with a long white patch which extends down the face as far as the nostrils, where it may end, or it may be continued on to the nose. Sometimes the forehead patch is absent, although the long patch down the face is present; sometimes the nose patch alone is present. It is so well known that there are three separate things present in the marking of a horse's face that each has received a separate technical name; any one alone, any two, or all three together may be present. These three characters are separate things, for they are each related to a different region of the horse's face; but as characters they are much more like one another than they are to those of the general coat colour; they refer not to the kind of pigment present, but to its distribution. It must not be thought that colour variation, such as can be seen

in the horse, are in any way peculiar to domestic animals. Wild animals may be very variable in colour; conversely, domestic animals may be very constant. Asses have long been domesticated in many parts of the world, but, unlike horses, they are almost always of the same colour.

Characters are not always tangible things of colour or of form. The time of the year at which a plant flowers, the number of young produced at a birth by an animal, the resistance of any organism to the parasitic invasion of another, are all examples of characters determined by gametic factors. I hope that these examples will convey a general idea of what is meant by a character and factor. There are difficulties in the way of understanding or of defining the term with exactness. Some characters seem to vary directly with the conditions which they obviate. For example, there can be no doubt that the pigment in the skin of man is to prevent damage to the delicate parts of the body by the sun's action, nor can there be any doubt that the fur of animals is to retain heat. The men of northern Europe are fairer than those of southern Europe; these are in turn less dark than the men of northern Africa, who are again much less dark than those who live near the equator. The fur of animals varies in the same way: rats which live in the hills have plentiful long, soft fur, while those which live in the hot plains have short, scanty fur; those living in the foot-hills are intermediate between the others as regards the quality of

their fur. Moreover, characters of this kind vary within the lifetime of the individual, for at the commencement of the cold season the hair of animals becomes long and plentiful, but when the hot weather returns the surplus hair falls off. In the same way, the fair human skin acquires some temporary pigmentation if long exposed to a tropical sun. Characters which vary with the conditions they obviate are not common; but varying conditions, such as heat and the sun's intensity, are few. Characters, therefore, do not all seem to behave in the same way. We know, however, that many characters are handed from parent to offspring in a definite manner.

A pure race is a group of organisms usually found living together which resemble one another very closely; in other words, we may define a pure race as one in which all the members possess the same number and the same kinds of characters. So many are the characters that go to make up an organism, and so little appreciable to our senses are some of them, that we may doubt whether a race of organisms is ever actually pure in the terms of the above definition; but some races are purer than others, and for convenience we may speak of a pure race. If we examine the successive generations of a pure race, we are apt to overlook the fact that each organism consists of an aggregate of separate characters; because all are so alike we may not see their composite nature. But it is not difficult to find two races of organisms which resemble one another very closely except

in one character: perhaps one race possesses a tangible structure which the other does not possess; perhaps as regards a particular quality, such as colour, the two races appear different. Races which differ from one another in this manner are by no means uncommon in nature; they may be found living side by side among the same conditions. It is by studying such different races, and the generations produced by cross-breeding, that we learn how characters are transmitted.

As an example of two races which differ from one another in one character only, we may consider two races of flowering plants which are unlike in the colour of their flowers. Two races of plants, the one bearing white flowers, the other bearing red flowers, are cross fertilized by placing the pollen of the one on the stigma of the other. The offspring plants which are raised from the seed of these unlike parents will all be alike if the parent plants were chosen from pure races, but we cannot know without trial what the offspring will actually be like. We know, however, that they must be of one of three kinds. They may all resemble one parent, or they may all resemble the other parent, or they may all be of a third kind which is more or less intermediate in outward appearance between the other two. In the case we are considering of a cross between a red- and white-flowered plant, all the offspring may be red, or they may all be white, or of an intermediate pink colour. We will consider these possibilities separately.

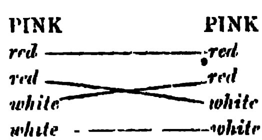
As a result of crossing the red and white varieties of the plant Mirabilis jalapa, seed is produced which give rise to pink-flowered plants; such plants are known as hybrids. The plants of this first hybrid generation are allowed to fertilize one another; they produce seed, the nature of which is tested by sowing and raising. It is found that the seed produced by this union is not of one kind, but of three kinds, and that the numbers of each kind bear a constant relation to one another. Of the offspring raised from this second cross one half will resemble their parents in having pink flowers, one quarter will resemble one grandparent in having red flowers, the other quarter will have white flowers, and so resemble the other grandparent. Moreover, these red- and white-flowered plants, the offspring of hybrid parents, are as pure in nature as their original grand-parents, for when tested by breeding them together, red with red and white with white, they always produce pure red- or pure white-flowered plants. But the pink-flowered plants which resembled their hybrid parents in the colour of their flowers behave in every way like their parents, for when they are bred together they give rise to red-, white-, and pink-flowered plants in the same constant proportions, 1 : 1 : 2. What is the explanation of this remarkable occurrence? We have seen that offspring arise from the germ cells of their parents. Germ cells are of two kinds, known as the male and female gametes, which unite and form a body called a zygote; the offspring arises from this zygote by

growth and cell division. In plants such as we are considering the male gametes are contained in the pollen grains, the female gametes in the ovules, from which the seed is ultimately formed. The red-flowering plants bear red flower producing gametes which may, for convenience, be termed red pollen and red ovules; similarly, the white-flowering plants may be said to possess white pollen and white ovules. Now, the behaviour of the pink hybrids on self fertilization can only be explained by supposing that their gametes do not bear a pink character, but are of the two kinds red and white, each present in equal numbers. In other words the germ cells of a hybrid are not of a hybrid nature. They are pure, but they are not all alike: half of them are like the pure gametes of one parent, the other half being like those of the other parent. This explanation will be understood more readily by an illustration in which capital letters show the nature of the plant as regards the colour of its flowers, and small letters show the nature of its gametes, *i.e.* their potentialities as producers of plants bearing flowers of such and such a colour.

The parents which belong to different pure races and the offspring of their union may, if our explanation be correct, be represented thus—

One parent.	The other parent.	One of the hybrid offspring.
RED	WHITE	PINK
red	*white*	*red*
red	*white*	*red*
red	*white*	*white*
red	*white*	*white*

And if our assumption as to the nature of the germ cells in a hybrid is correct, on fertilizing one hybrid with another, a mixture of red and white pollen meets a mixture of red and white ovules. It is assumed that there is no special attraction of one kind for its own or for the other kind; we must therefore suppose that in the meeting of gametes one kind is just as likely to meet its own kind, as it is to meet the other, for both are present in equal numbers. Therefore, for every red pollen grain which seeks and finds a red ovule, a red pollen grain must find a white ovule, and for every white pollen which joins a white ovule another must join a red ovule. The union between hybrid and hybrid therefore be represented in this way—



The result of this cross is therefore, 1 red red, 1 white white, and 2 mixed zygotes (the combinations red white and white red are the same). We have seen that this is what is actually obtained in experiment. One out of four, or a quarter of the total offspring, bear red flowers, and breed truly and resemble one of their grandparents in every way; another quarter bear white flowers and resemble their other grandparent, while the remaining half are hybrids like their parents.

The offspring which result from the interbreeding of the hybrids may be shown thus—

RED	PINK	PINK	WHITE
red	*red*	*red*	*white*
red	*red*	*red*	*white*
red	*white*	*white*	*white*
red	*white*	*white*	*white*

We see, then, how simple is the explanation of the facts on the assumption that the factors in the gametes of a hybrid are pure, but of different kinds. That the explanation is a true one is further shown by crossing a pure form with a hybrid form: the pure red variety with the pink hybrid. The result of such a cross may be shown thus—

PINK	RED
red	*red*
red	*red*
white	*red*
white	*red*

If our assumption is correct, we shall expect one half of the offspring to be pink and the other half to be red, and this result is actually obtained in experiment.

In order to present the problem in its simplest form, I have chosen a case in which the hybrids resulting from the first cross do not resemble either one or the other parent, but are of an intermediate kind. It is more usual to find that the first generation of hybrids resembles in outward appearance one or other of their parents. For example, if we choose a tall variety of pea plant and a dwarf of the same, and cross them, we find that their offspring are all of the tall variety. Tallness is said to

be dominant to dwarfness, which is called recessive to tallness. Using the same method of illustration as before, we may show each of the parents and any one of the many offspring in the following way:—

One parent.	The other parent.	One of their hybrid offspring.
TALL	DWARF	TALL
tall	*dwarf*	*dwarf*
tall	*dwarf*	*dwarf*
tall	*dwarf*	*tall*
tall	*dwarf*	*tall*

The offspring which result from crossing the hybrids may be shown thus

TALL	TALL	TALL	DWARF
tall	*tall*	*tall*	*dwarf*
tall	*tall*	*tall*	*dwarf*
tall	*dwarf*	*dwarf*	*dwarf*
tall	*dwarf*	*dwarf*	*dwarf*

Three quarters of the second generation of hybrids will therefore be tall and one quarter will be dwarf. The dwarf kind will be pure, and will give rise only to dwarf offspring when interbred; but the tall ones will be of two kinds: one-third of them will be pure tall and will breed purely, but two-thirds of them, although outwardly tall, will be hybrid, and on breeding will behave in exactly the same way as the first generation of hybrids behaved.

Cases such as that of Mirabilis jalapa, in which the first generation of hybrids is very different in outward appearance from either of its parents, are comparatively rare. Another well-known case of the same kind is that of the Andalusian fowl. Birds of this breed are of a slate

blue colour with a blackish neck; they look like a pure breed, but if a large number of offspring—for example, 100—be hatched from their eggs, only about 50 of them will be blue; of the others, about 25 will be black and 25 will be white. If we wish to rear 100 fowls all of which will be of the blue Andalusian type we must cross the black and the white birds together. Organisms such as the pink Mirabilis and the blue Andalusian fowls are technically called heterozygotes.

It is probable that dominance alone indicates the existence of a factor, and that it is incorrect to speak of a recessive factor; for example, albinism or total absence of pigment, is in all known cases recessive to any kind of colour. Albinism is not the result of a factor, but is the result of the absence of any kind of colour factor. Again, it has been found that blue eyes in man are always recessive to brown eyes; the blue colour of the human iris is not due to a blue pigment, but is a result of the absence of pigment from the iris. A brown eye is due to a factor which produces brown pigment in the iris. Brown eyes are therefore dominant over blue eyes.

The foregoing is an elementary account of a most interesting and important subject which is growing rapidly at the present day. The result of crossing organisms which differ from one another in more than one factor, as well as many other important discoveries, cannot be mentioned here.

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(Abbreviations: def., *definition*; r., *reference*.)

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THE END

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